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X-RAYS AND RADIUM

IN THE TREATMENT OF

DISEASES OF THE SKIN

BY

GEORGE MILLER MacKEE, M.D.

ASSISTANT PROFESSOR OF DERMATOLOGY AND SYPHILOLOGY, COLLEGE OF PHYSICIANS
AND SURGEONS, COLUMBIA UNIVERSITY; FELLOW OF NEW YORK ACADEMY OF MEDICINE;
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MEDICAL ASSOCIATION; FORMER EDITOR OF JOURNAL OF CUTANEOUS
DISEASES; CONSULTING DERMATOLOGIST AND SYPHILOLOGIST,
ST. VINCENT'S HOSPITAL, ETC.

ILLUSTRATED WITH 250 ENGRAVINGS AND 22 CHARTS

LEA & FEBIGER
PHILADELPHIA AND NEW YORK

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THIS WORK

IS RESPECTFULLY AND SINCERELY DEDICATED

TO THE AUTHOR'S CHIEF

PROFESSOR JOHN ADDISON FORDYCE

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Several of the chapters, particularly those dealing with general physics and biology, are compilations, in the preparation of which several well-known books were liberally used. Special credit is given the following:

Colwell, H. A., and Russ, S.: Radium, X-rays and the Living Cell, London, 1915, G. Bell and Sons.

Pusey, W. A. and Caldwell, E. W.: Roentgen Rays in Therapeutics and Diagnosis, Philadelphia, 1904, W. B. Saunders and Co.

Kaye, G. W. C.: X-rays, N. Y., 1917, Longmans, Green and Co.

Rutherford, E.: Radioactive Transformations, New Haven, 1906, Yale University Press.

Campbell, W. R.: Modern Electrical Theory, Cambridge, 1913, Cambridge University Press.

Shearer, J. S.: Chapter on Physics, X-rays Manual, U. S. Army, 1917, L. Middleditch Co.; U. S. X-ray Manual, New York, 1918, Paul B. Hoeber.

Four illustrations (epithelioma) were contributed by Dr. William Allen Pusey, four (rhinoscleroma) by Dr. M. J. Wunderlich of Guatemala, two (synovial lesions of the skin) by Dr. Richard L. Sutton and two (lupus vulgaris) by Dr. Jay F. Schamberg.

Forty-six of the charts, tables, and clinical illustrations have been borrowed from books or journals, credit for which is given under the illustrations or in the text. A few of these were borrowed from catalogues and no credit given. All but one commercial house consented to the use of their illustrations without credit. Most of the illustrations, tables, and charts are from the combined collection of Dr. Fordyce and the author. Seventy of the illustrations have been previously published in the Journal of the American Medical Association, the New York Medical Journal and The Medical Record. Detailed credit is given in the bibliography.

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which the stream was focused, became hot. As a result of these and other experiments Crookes maintained that the luminous stream of Geissler and Hittorf was composed of minute particles; to this stream he gave the name cathode rays.

The work of Crookes excited a great deal of interest and many eminent physicists began to study the cathode stream. In 1892 Hertz placed discs composed of various substances in the path of the cathode stream. In this way he determined that the cathode rays would penetrate a very thin piece of aluminium foil. In order to study the cathode rays outside the tube Lenard, who had been working with Hertz, sealed a piece of aluminium foil in the large end of a Crookes' tube. He at once determined that the radiation passing through or from the aluminium window was able to penetrate substances that were opaque to ordinary light and after passing through such substances it was capable of causing a fluorescence of the platinocyanide of barium. Furthermore, he noted that this filtered radiation was capable of affecting a photographic plate in much the same manner as ordinary light. It is possible that the Lenard tube, or a modification thereof, will some day be of therapeutic value. In recent years it has been found that the beta rays of radium will effect certain results that cannot be duplicated with *x*-rays. Inasmuch as these beta rays are identical with, although more penetrating than the cathode rays, one is led to believe that the latter would possess a similar therapeutic value if it were possible to employ them for practical purposes.

Lenard was under the impression that all the phenomena observed by him were due to the cathode rays, but as pointed out by Caldwell and others, there can be little doubt but that Lenard, Hertz and other investigators had actually produced and observed *x*-rays but had failed to recognize or isolate them. This great feat was left to the fortunate Roentgen. As a matter of fact several physicists were investigating the mysterious fogging of light-protected photographic plates in their laboratories when Roentgen's discovery was announced.

In the latter part of 1895 Roentgen was actuating an ordinary Crookes' tube, with a concave cathode, which he had enclosed in a cardboard box, when he noticed that some crystals of platinocyanide of barium, lying at some distance, fluoresced. He then placed various objects between the source of radiation and the barium salt and soon ascertained that the mysterious, invisible radiation would penetrate any material in accordance, roughly, with its density. He determined (erroneously) that the radiation could not be refracted, reflected or deflected. It was obvious to Roentgen that this radiation was not the same as the cathode rays of Crookes, Hertz and Lenard. After ascertaining that the new radiation was developed on the glass wall of the tube at the point of contact with the cathode rays, he endeavored to determine the exact nature of the new radiation, failing in which he modestly termed it the *x*-rays, probably on account of the significance of the letter X in mathematical formulæ. By suitably protecting

photographic plates from ordinary light Roentgen was able to obtain shadowgraphs of various opaque objects including an image of his own hand with a silhouette of the bones. This was really the birth of roentgenography. At the same time he coated a piece of cardboard with an emulsion of barium platinocyanide and used it as a fluorescing screen or fluoroscope—the birth of fluoroscopy.

Roentgen communicated his great discovery to the world through the medium of the Physico-Medical Society of Würzburg in December, 1895. The communication was at once published in every civilized country and the news was received with astonishment, interest and delight. Physicists, electrical engineers and practical physicians immediately began to experiment and investigate. The power of electric generators was increased; induction coils were wonderfully improved as, also, were static machines. But as pointed out by Caldwell, Mr. Herbert Jackson made what was probably the greatest single step of the time in the way of a practical addition to the necessary apparatus. Making use of Crookes' discovery that the cathode stream could be focused and intercepted, he focused the cathode rays on a platinum disc placed within the tube, thus creating the first real focus tube. In an incredibly short time *x*-ray operators were making routine examinations for fractures, dislocations and foreign bodies.

During this practical work and scientific investigation, several experimenters noticed that after a prolonged exposure to *x*-rays an erythema of the skin was produced and in some instances a dermatitis and even deep ulceration occurred. This was recognized as an *x*-ray reaction. This biological effect particularly attracted the interest of Shiff and Freund and it was only a month or two after Roentgen's announcement that they suggested the use of the *x*-rays in the treatment of disease. This was the birth of roentgentherapy. The first therapeutic attempts were made in nevus, hypertrichosis, cancer and tuberculosis.

Within a few months the medical press was literally swamped with accounts of the more or less successful treatment of various maladies with the *x*-rays. The fact that the new agent seemed to exert a beneficial effect on malignant tissue led to the immediate belief that there was at last a cure for this disease. And the same was true of tuberculosis.

The history of roentgen therapy can be divided roughly into three eras—optimistic, pessimistic and realistic; this is particularly true of this country. At first enthusiasm and carelessness overcame caution. Many physicians installed apparatus and attempted to employ the *x*-rays for practical therapeutic purposes, without making a study of the subject. Even the scientific and conscientious workers did not at first realize that they were dealing with an exceedingly dangerous agent. It was natural, therefore, that many patients received serious injuries. Not only were patients injured, but operators, by repeatedly testing the penetrability of the rays by inserting their hand between the tube and a fluorescing screen, developed an erythema which in many

instances led to serious sequelæ. These facts, together with the discovery by Brown and Osgood that sterility was produced by the *x*-rays naturally caused operators to be a little more cautious. However, optimism reigned until about 1906. During those years the rays, to a large extent, were empirically used and they were tried out on nearly every chronic disease. The literature was misleading as it was full of case reports of wonderful cures, the occasional paper from the pen of a good man being ignored or overlooked by the average *x*-ray operator of the period and in spite of repeated warnings from capable men the "radiomaniacs" held the reins.

It was soon found that the *x*-rays were capable of producing a cure in only a certain percentage of cases of the basal-cell type of cutaneous epithelioma, that it was exceedingly unreliable in malignant cancer and that, in any event, it did not replace surgery. This was a keen disappointment. The *x*-rays proved practically useless in pulmonary tuberculosis. This was another great disappointment. Finally the lay public and even the greater part of the medical profession not only lost faith in the therapeutic value of the the *x*-rays but considered them an exceedingly dangerous and almost useless remedial agent. During this early period, there were some very curious theories advanced. For instance it was claimed that quinine and other phosphorescing substances given internally caused diseased tissue to respond more readily to the beneficial influence of the *x*-rays. The Cornell tube, a tube of lead glass with a soda glass window patterned after Piffard's well-known tube, was said to be incapable of effecting an *x*-ray reaction providing the soda glass window was placed against the skin. Another roentgenologist asserted that *x*-ray "flashes" or visibly intermittent *x*-rays produced superior results and were associated with very little danger. Another theory brought forward was that the *x*-ray reaction was caused by glass being carried from the wall of the tube into the skin. In fact the literature contained many erroneous and even dangerous theories. The unverified accounts of marvelous results, the injurious effects observed as time went on, the fact that there was no satisfactory method of estimating the amount of radiation administered, and because the earlier claims were not substantiated, finally resulted in the period of depression or pessimism which lasted from about 1906 to about 1910 or 1912.

During this period there were a number of scientifically inclined roentgenologists who recognized both the advantages and limitations of the *x*-rays and who also recognized the necessity of standardizing the work and of devising accurate methods of measurement.

Among the first roentgen therapeutists in this country were William Allen Pusey, Charles Warren Allen, Henry G. Piffard, Stelwagon, Pancoast, Williams and others. Piffard's articles on "radiomaniacs" and "radiografters" were very pertinent and his articles on instruments of precision and *x*-ray measurement were equally instructive. In Europe the illustrious early therapeutists were Schiff, Freund, Béclère,

Brocq, Belot, Schönberg, Hall Edwards, Heinecke, Holzknecht, Kienböck, Schmidt, Benoist, Walker, Oudin, Barthelémy, Walsh, Morris, Sequeira and others.

For a number of years the greatest interest was associated with the development of new exciting apparatus and instruments of precision or of measurement. In this country the static machine reached perfection. Some even went so far as to build vertical machines possessing fifty or more plates. Improvements in the Rhumkorff coil, however, soon caused this apparatus to displace the static machine and the coil was used almost exclusively until the advent of the interrupterless transformer which was placed on the market by Snook, of Philadelphia, in 1908. This machine, by doing away with the troublesome interrupter, and by providing a reliable and easily controlled unidirectional current of great strength, proved to be one of the big additions to roentgenology. The interrupterless transformer has been modified and improved, but it has not yet been superceded.

Numerous methods and instruments were devised for the purpose of estimating the quality or penetrability of the *x*-rays. One of the first instruments for the purpose was the spintermeter of Béclére which was simply a calibrated, adjustable, parallel spark gap. Then Benoist, in 1901, produced his radiochromometer. Since then there have been numerous instruments devised for this purpose (Walter penetrometer, Wehnelt penetrometer, Heinz-Bauer qualimeter, voltmeters, etc.), but the spark gap has been and still is the favorite practical method of measuring quality.

For a number of years it was the custom to estimate the quantity of radiation administered by establishing various constants, such as milliampèrage, spark gap, number of interruptions per second, distance of anode from skin, etc. This was an exceedingly difficult thing to do before the advent of the Coolidge tube and the interrupterless transformer and the method was so uncertain and dangerous that many investigators devoted a great deal of time in an endeavor to perfect some method of direct measurement. Kienböck established the law that "the degree of reaction depends upon the quantity of *x*-rays absorbed by the skin." Also, the law relative to the intensity of the rays being inversely as the square of the distance or directly as the sine of the angle, became well established and was of great help to therapeutists. In 1902 Holzknecht presented the first instrument for direct measurement of quantity—this was called the chromoradiometer. It consisted of a capsule containing a liquid of secret formula which changed color when exposed to the *x*-rays. By employing a graduated color index one could read the dose in units. This method was found unreliable and was discarded for his second instrument, the Holzknecht radiometer.

In the meantime numerous instruments and methods designed for this purpose made their appearance. Among the most notable was Kienböck's idea of employing strips of standardized photographic

developing paper. It should be stated here that Stern of New York was the first to suggest the photographic method of measurement. Then Sabouraud and Noiré developed their radiometer, which depended upon the color changes produced by the *x*-rays in barium platinocyanide. The radiometers of Holzknecht, Bordier, Hampson, and Corbett are all modifications of the Sabouraud-Noiré instrument.

In the early days *x*-ray tubes were a source of great trouble. It was difficult to regulate the vacuum and impossible to maintain it when heavy currents were used. And with heavy currents the anode would melt. Tungsten targets and water-cooled and air-cooled tubes, improved vacuum pumps and vacuum regulators, lessened these difficulties considerably. But in spite of all the marked improvements in gas tubes there was no perfectly satisfactory *x*-ray tube for therapeutic purposes until 1914, when Coolidge announced his electron tube—a discovery that at once revolutionized roentgentherapy.

In addition to the accomplisments of scientifically inclined physicians and electrical engineers, it must not be forgotten that many pure physicists persistently investigated the *x*-rays and radioactive substances from the very moment of their discovery. The work of these men paved the way for many if not all the improvements in the technic of recent years and, of course, as a result of their tireless endeavors we now possess a fairly reliable conception of the nature of the *x*-rays and of the radioactive substances. A brief resumé of the investigations of these scientists will be found in the chapter on Physics.

At last the value and limitations of the *x*-rays in the treatment of disease has been fairly well established; especially is this so of cutaneous affections. The improvement in technic, increased knowledge regarding possibilities and limitations, the recognition that roentgenology is a specialized subject, and especially the fact that radiodermatitis can be avoided with a reasonable degree of certainty, have caused a gradual restoration of confidence and this confidence will be permanent if the work can be kept out of the hands of unscrupulous, overenthusiastic and careless individuals.

RADIUM.

Radium was discovered by Mme. Curie in 1898, three years after Roentgen's famous announcement. The result of the research appeared as a joint paper by Prof. and Mme. Curie and G. Bemont.[1] Like Roentgen's discovery the isolation of radium was preceded by pertinent investigations, this time by Becquerel, Mme. Curie and others.

As we have seen, there was considerable controversy in 1895 relative to the nature of the cathode rays of Crookes. Finally, in 1897, J. J. Thompson proved definitely that the cathode stream consisted

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[1] Compt. rend., 1898, cxxvii, 1215.

of negatively charged particles moving with great velocity. He determined that these particles were much smaller than the most infinite particle of matter known to scientists, namely, the atom of hydrogen. He concluded that they represented a new state of matter and designated them by the name electrons. Now it will be recalled that Thompson, Lenard, Crookes and others had called attention to the fluorescence of the glass wall of the tube under the bombardment of the cathode rays. After the discovery of the x-rays it was conceded that the cathode stream was its parent, but it was also erroneously thought that the fluorescence of the glass wall of the tube had some influence in the production of the roentgen rays. With this idea in mind several physicists studied various substances that phosphoresced under the influence of light. Becquerel, for instance, protected a photographic plate from ordinary light and exposed it to the double sulphate of potassium and uranium. The plate became fogged after a prolonged exposure, showing the presence of rays capable of penetrating supposedly opaque material. It was noticed, too, that the same effect was obtained even when the potassium-uranium salt had ceased to phosphoresce. Later, the radiation obtained from pure uranium was shown to possess characteristics similar to those of the x-rays. Later still it was determined, as a result of the work of Becquerel, Curie, Villard and others that uranium emitted three types of radiation, namely, alpha, beta and gamma rays.

Immediately after Becquerel's discovery Mme. Curie conducted a systematic examination of various substances for evidence of radioactivity and found that the element thorium demonstrated similar properties observed in uranium and to about the same degree. To quote from Rutherford: "An examination was then made of the natural minerals which contain thorium and uranium and here an unexpected result was observed. Some of these minerals were found to be several times more radioactive than pure uranium or thorium and in all cases the uranium minerals showed four to five times the activity to be expected from the percentage of uranium present. Mme. Curie found that the radioactivity of uranium was an atomic property, *i. e.*, the activity observed depended only on the amount of the element uranium present and was not affected by its combination with other substances. This being so, the large activity of the uranium minerals could only be accounted for by supposing that another substance was present, which was far more active than uranium itself.

"Relying on this hypothesis, Mme. Curie boldly proceeded to see if it were possible to separate chemically this unknown active substance from uranium minerals. By the courtesy of the Austrian Government, she was presented with a ton of uranium residues from the State Manufactory at Joachimsthal, Bohemia. In this locality there are extensive deposits of uranite commonly called pitchblende, which are mined for the uranium they contain. This pitchblende consists mainly of uranium, but also contains small quantities of a number of rare elements.

"As a guide to the separation of the active substance, Mme. Curie employed a suitable electroscope to measure the ionization produced by the active body. After each chemical separation, the activities of the precipitate and of the filtrate evaporated to dryness were separately examined and in this way it was possible to ascertain whether the active substance had been mainly precipitated or left behind in the filtrate.

"The electric method was thus used as a rapid means of qualitative and quantitative analysis. Proceeding in this way, Mme. Curie found that not one but two very active substances were present in the uranium residues. The former of these, which was separated with bismuth, was called polonium, in honor of the country of her birth and the latter, which was separated with barium, was called radium. This latter name was a happy inspiration, for the activity of this substance in a pure state is at least two million times that of uranium."

The development of the theory of ionization of gases by Wilson, Thompson, Rutherford, and Townsend (1896 to 1899), proved of great value in the search for radioactive elements and in the comparative study of the physics of these elements and of the *x*-rays.

In 1899 and 1900, as a result of the work of Giesel, Becquerel, and Villard, the alpha, beta and gamma rays of radium were separated and studied. The beta rays were shown to be similar, if not identical, to the cathode rays—negatively charged particles travelling at great velocity, deflected by a magnet and possessing considerable penetrating power. The alpha rays were also found to consist of particles having less velocity than those of the beta rays, possessing very little penetration and deflected by a magnet in the opposite direction from the beta rays—therefore the charge was positive instead of negative. These rays were later shown to be similar to the canal rays of the *x*-ray tube.

The gamma rays were found to be very similar to the *x*-rays in that they were very penetrating, they produced the same ions as did the *x*-rays and like the latter the gamma rays could not be deflected, reflected nor refracted by any means known at the time.

At about this time Rutherford showed that thorium emitted a gaseous radioactive substance which was called an emanation. Then Mme. Curie demonstrated that all bodies placed in the immediate neighborhood of radium became temporarily active. This induced activity was caused by the deposit from the radium emanation.

In 1902 Rutherford and Soddy demonstrated that a very active substance, called thorium X could be separated from thorium. The new substance would lose its activity in time while the thorium, freed from thorium X, would spontaneously produce a new supply. It was determined that thorium emanation was derived from thorium X and not directly from thorium. Knowing that the radioactive property of an element was atomic and, therefore, that the alteration must occur in the atom and not in the molecule, Rutherford and Soddy advanced their well-known disintegration theory. In the last few years physicists have considerably advanced our knowledge relative

to the nature of the radioactive substances. A brief summary of these investigations will be found in the chapter on physics.

Radium therapy began with the famous "Becquerel burn." In 1901 Becquerel placed a tube of radium in the pocket of his waistcoat where it remained for several hours. A week or two afterward a severe inflammation appeared in the skin underneath the radium. Besnier examined this dermatitis and expressed the belief that it was due to the radium. Walkoff avers that he reported a case of radium dermatitis in 1900 and, therefore, claims priority. Prof. Curie then made some experiments on his own person and conclusively proved that the radiation was capable of effecting an inflammatory reaction in normal skin. Being cognizant of the early results of roentgen-therapy and familiar with the inflammatory reactions obtained by Becquerel and Curie, Besnier suggested the use of radium as a therapeutic agent. For this purpose Becquerel loaned some radium to Danlos of the hôpital St. Louis, where it was soon found that the new agent exerted a beneficial effect on a number of diseases. Danlos' work was continued by Masotti and the results were published by the latter in book form at a later date.

The pioneers in Europe were Lazarus, Mache, Szilard, Danlos, Wickham and Degrais, Bashford, Becquerel, Czerny, Freund, Bayet, Schiff and others. In this country Abbe of New York was probably the first physician to employ radium for practical purposes.

Radium therapy developed more slowly than did roentgen therapy largely because the substance was expensive and difficult to obtain. A few years ago this branch of the medical science received a great stimulus through the repeated announcements that large quantities of radium would cure cancer. The propaganda, while harmful at the time, really accomplished considerable good as it encouraged several institutions to purchase large amounts of the element which was placed under the control of scientific and conscientious observers. In consequence the true value of radium in the treatment of cancer is being determined. The results to date while encouraging do not realize the exaggerated reports of some of the earlier writers.

Radium has been found of great value in the treatment of many diseases and thanks to recent investigations, excellent results and conservative writings of well-informed and scientific men, radium therapy is now on a safe foundation.

In the preparation of this historical sketch the author acknowledges the liberal use of the following works: Pusey, W. A. and Caldwell, E. W.: Roentgen Rays in Therapeutics and Diagnosis, 1904, Philadelphia, W. B. Saunders & Co.; Belot, J.: Radiotherapy in Skin Diseases, 1905, N. Y., Rebman Co.; Kaye, G. W. C.: *X*-rays, 1917, N. Y., Longmans, Green & Co.; Colwell, H. A. and Russ, S.: Radium, *X*-rays and the Living Cell, 1915, London, G. Bell & Sons; Newcomet, W. S.: Radium and Radiotherapy, 1914, Philadelphia, Lea & Febiger; Wickham and Degrais: Radiumtherapy, 1910, N. Y., Cassell & Co.; Rutherford, E.: Radioactive Transformations, 1906, New Haven, Yale University Press; Lazarus, P.: Handbuch der Radium-Biologie und Therapie, 1913, Wiesbaden, J. F. Bergmann; Towle, H. P.: A Review of the Literature of the Therapeutic Use of the *X*-rays, Boston Med. and Surg. Jour., 1901, cxliv, p. 343; Williams, F. H.: The Roentgen Rays in Medicine and Surgery, 1903, N. Y., The Macmillan Co.; Allen, C. W.: Radiotherapy, Phototherapy, Radium and High-Frequency Currents, 1904, Philadelphia, Lea Brothers & Co.

CHAPTER II.

GENERAL PHYSICS.

THE ELECTRON THEORY OF MATTER.

SINCE the discovery of the x-rays and the radioactive elements the physics of matter in general has become somewhat complicated. Reduced to the simplest terms the present conception of matter, as based upon the electric or electronic theory, is that the molecule is composed of atoms and the latter contain units of negative and positive electricity. The negative units are called electrons. They are supposed to travel at high velocity within the atom and they are held in equilibrium either by positively charged particles or by a sphere of positive electrification of a magnitude equal to the sum total of the electrons. Electrons are thought to be about $\frac{1}{1800}$ the size of the smallest particle of matter previously known, namely, the hydrogen atom. As expressed by Shearer, "if we could magnify sufficiently both electrons and the surface of polished metal, the irregularities of the surface would appear like mountains and valleys, while the electrons would be almost too small to be seen."

Some scientists believe that the electron has no material nucleus, but that the apparent mass is entirely electrical. It has been demonstrated that a charged body in motion possesses electrical mass in virtue of this motion, that this mass consists of stored-up electromagnetic energy, that it increases with the velocity of the body and that it exactly simulates the properties of mechanical mass. It is possible, therefore, that matter, as revealed to our senses is of electrical origin. The atoms of the chemical elements probably differ in the number, motion and arrangement of electrons but the latter are always the same regardless of the element.

Matter is not stable. Molecules are constantly breaking up and reforming under the influence of many physical forces such as light, heat, cold, pressure, etc. Atoms, too, break down under the action of physical forces. Some atoms undergo spontaneous disintegration. When an atom breaks down from any cause electrons, or positive corpuscles or both, may be liberated. If an electron is suddenly started in motion or its motion is suddenly arrested or the path of this motion is suddenly changed, electromagnetic waves are produced. A fair appreciation of the manner of production and the characteristics of these waves is of considerable importance to the student of radiology.

Electromagnetic Waves.—It is well known that light consists of electromagnetic waves or vibrations emitted from a luminous body as

a result of atomic disturbance, that these waves possess a velocity of 186 thousand miles a second, and that they are transmitted through the medium of a hypothetical substance known as ether. The ether is supposed to occupy all space including that between and in atoms of all matter. The waves vary markedly in length and waves of different length produce different impressions on our senses. When passed through a prism or passed through or reflected from a diffraction grating (a glass plate on which many regularly spaced fine lines have been ruled) the various wave lengths of which white light is composed, are sorted out and may be separately studied. This series of wave lengths constitutes a spectrum. The visible spectrum consists of wave lengths ranging from 7500 to 3800 angström units (an angström unit is one hundred-millionth of a centimeter or one ten-thousandth of a micron). Beginning with the long waves, which produce an appreciation of the color red on our sense mechanism, we pass through the orange, yellow, green, blue, etc., to the short waves which are recognized in the spectrum as violet. Shorter wave lengths (3800 to 600 angström units) represent ultraviolet rays, recognized by photographic methods. Still shorter electromagnetic waves (from 600 to $\frac{1}{10}$ angström unit) comprise x-rays and radium gamma rays. On the other end of the spectrum we have the infra-red rays, wave lengths of from 7500 to 300,000 angström units which are appreciated by our senses as heat, which are separated by passing solar light through rock salt and which are estimated by especially constructed thermometers. Finally there are the Hertzian waves (wireless waves) with a wave length ranging all the way from a fraction of an inch to several miles. These are produced by electric oscillations and the wave length depends on the electromagnetic inductance and the electrostatic capacity of the oscillating system. It will be seen, therefore, that electromagnetic waves vary enormously in length and that the characteristics, that is, the effect on our senses or on matter, depend upon the wave length. They are produced in various ways (spontaneous—sun, radium; electrically—incandescent lamps, x-rays, wireless telegraphy; chemically —combusion, etc.), but their production always entails molecular, atomic and electronic action. The assumption is that electromagnetic waves are produced only when there is a disturbance in the electric components of atoms, possibly a change in the velocity of electrons, and the length of such waves seems to depend upon the suddenness with which the change in the motion of the electrons is brought about. Regardless of the wave length electromagnetic waves all travel at the same speed, namely, 186 thousand miles per second, therefore Hertzian waves, light waves, ultraviolet rays and x-rays all travel at the same speed. The wave lengths are determined by dividing the velocity by the frequency and the latter is synonymous with electric oscillation or vibration.

Electricity.—An electron is the smallest quantity of electricity detected. It is the smallest unit of negative electricity. When an

electron leaves an atom of matter the remaining part of the atom is said to be positively charged but with the same amount as the electron is negative. That is, a unit of negative electricity and a unit of positive electricity added together produce a zero electrical effect or the atom is said to be neutral. A body which has an excess of electrons is said to be charged negatively; a body which, originally neutral, lost some electrons is said to be charged positively. Charges which are alike, that is, two positive charges or two negative charges, repel each other, while a positive and a negative charge attract each other. The charge on an electron or a body having any number of electrons in excess or having a deficiency of electrons is called *quantity* of electricity; negative or positive as the case may be. If this electricity is moving either through a wire of metal or through a liquid or through a gas we have a *current* of electricity. A current of electricity has magnetic properties about it, which the same electricity at rest has not. This phenomenon of a current of electricity makes it possible to measure currents of electricity by instruments called galvanometers in general and which when used for specific purposes are called ammeters, milliammeters, voltmeters, etc.

Potential and Difference of Potential.—If we have a body charged with electricity, say positive, *i. e.*, the body had lost some of its electrons; and we should bring another positively charged body (*e. g.*, a pith ball covered with tin-foil and hung on a string) in the neighborhood of the first one, work will have to be done against the force of repulsion which exists between the two like charges. The closer together we wish to bring the bodies the more work has to be done. If the positive charge on the pith ball is a unit the work done in bringing the charge from a great distance to a definite point is said to be the *potential* at that point due to the charge on the first body. Since less work is done in bringing the unit charge from a great distance to a point not so near the charged body as the definite point mentioned above, the potential is also less. Therefore, there exists a difference of potential between these two points and it is equal to the work done in bringing the unit charge from the latter point to the former point. Suppose we have two bodies charged with electricity but so that a difference of potential exists between these bodies, *e. g.*, one is charged positively and the other negatively. If we connect these two bodies together electrons will flow from the one having an excess of electrons (the negative) to the one having a deficiency of electrons (the positive). In a metal the motion of these electrons constitutes the current and the motion of the electrons is due to the difference of potential existing between the two bodies. The difference of potential may then be thought of as the difference of electrical condition of the two bodies due to which electrons move from one body to the other through the conductor. From the above, it is seen that potential is of the nature of work or energy in transferring a unit charge. It is *not* a force.

Ionization.—When any agent causes the separation of an electron from its atom or molecule we say the atom is ionized. The electron

by itself or after attachment to a neutral atom or molecule is called the negative ion while the remainder of the atom or molecule is called the positive ion. Among the agents which will ionize a gas are the *x*-rays, radiations from radioactive substances, heat and ultra-violet light.

Current.—If the gas between two plates, called electrodes, which are at a difference of potential is ionized, the negative ions will move in one direction and the positive ions will move in the opposite direction and the combined motions of the positive and the negative ions constitute the electric current through the gas.

This current may be demonstrated by an electroscope. If the leaves of an electroscope are positively charged the walls of the containing vessel will be negatively charged. The law of attraction and repulsion will cause the leaves to diverge. If the air in the electroscope is now ionized, the negative ions are attracted to the positively charged leaves while the positive ions collect on the wall of the vessel. Thus the charge of the instrument will be neutralized and the leaves will converge. The estimation, by means of the electroscope, of the ionizing power of ionizing agents constitutes a very sensitive method of measuring the intensity of the *x*-rays and the radiation emitted by the radioactive substances—ionization method used by physicists.

In case of liquids, if a salt or an acid is dissolved in a solvent, say water, some molecules of that salt or acid break up into parts, called ions, one of which is positive and the other negative. For example, sulphuric acid H_2SO_4, breaks up (only a small part of it) into positive ions, H_2, and the negative ions SO_4; silver chloride, AgCl, breaks up into positive ions of Ag and negative ions of Cl. The movement of these ions constitutes the current through the liquid. The total amount of electricity transferred from one electrode to the other is transferred by these ions.

In case of a solid, there exist "free" electrons among the atoms and molecules of the solid aside from the electrons in the atoms themselves. These electrons move about in much the same manner as the molecules. When this solid is placed between two points having a difference of potential between them they move and their movement constitutes the current in the solid. Solids which have an abundance of free electrons conduct electricity readily and are called good conductors, while solids which have only a few free electrons are poor conductors or insulators.

The carrying of electricity by the ions in a liquid gives us a way of defining the current of electricity in practical units. The unit is the *ampère* and it is that current which results from the quantity of electricity carried by 0.001118 gram of silver past a point per second; *i. e.*, if silver is deposited by the current, an ampère will deposit 0.001118 gram of silver every second from a silver salt solution.

The quantity of electricity associated with the 0.001118 gram of silver ions is a coulomb; that is, a coulomb is the quantity of electricity

carried past a point in one second by a current of one ampère; 1 ampère × 1 second = 1 coulomb. The current is measured by the ammeter, or if the current is very small by the milliammeter.

Resistance.—Since a current is a movement of electrons or of ions, it is obvious that this movement is obstructed by the molecules of the conductor and that this obstruction may be different for different conductors. The obstruction to the passage of the current of electricity is called resistance. The unit of resistance is the *ohm*. The ohm is the resistance offered to a constant electric current by a column of mercury at 0° C., 14.4521 grams in mass, of a constant cross-sectional area and of a length of 106.3 cm.

Potential Difference, Electromotive Force, Voltage.—The term difference of potential has been explained above. Electromotive force, or E.M.F., is a term given to the cause, no matter what its nature is, which is capable of producing a difference of potential. E.M.F. is therefore measured in the same units as potential difference. It is frequently confused with it. The term electromotive force is an unfortunate one because E.M.F. is not a force at all but rather work or energy. The term voltage is a common although "loose" term, being used for potential difference or for E.M.F. or for both.

The practical unit of difference of potential or of E.M.F. is the *volt*. A volt is that potential difference which will cause a current of one ampère to flow through a conductor whose resistance is one ohm. Potential difference is measured by means of a voltmeter. The length of a spark gap under suitable conditions is also used to measure large differences of potential.

Power.—Electrical power is like mechanical power, namely, the rate of doing work: that is, the total work done or energy used divided by the time in which it was done. Since potential difference is of the nature of work per unit charge, and current of electricity is the number of unit charges per second, it follows that the product of the potential difference and the current is work per second, or power. Using the practical units the potential difference is measured in volts, the current in ampères and volts × ampères = watts.

For example, the terminals of a house circuit have a difference of potential of 110 volts, an ordinary 16-candlepower carbon lamp takes $\frac{1}{2}$ ampère, and therefore, the energy in lighting this lamp is consumed at the rate of 110 volts × $\frac{1}{2}$ ampère = 55 watts. The ordinary electric toaster takes $4\frac{1}{2}$ ampères on a 110-volt circuit and therefore consumes energy at the rate of 110 volts × $4\frac{1}{2}$ ampères = 495 watts or nearly one-half kilowatt.

PHYSICS OF THE X-RAY TUBE.

A description of the various *x*-ray tubes will be found in Chapter IV. Suffice it to say here that there are in general two types of tubes, namely, the gas tube and the Coolidge tube. The latter is pumped as free of air and other gas as possible; a little gas is allowed to remain in the

former. Roentgen tubes have two electrodes—cathode (negative) and anode or target (positive). To actuate such a tube it is necessary to have a suitable high potential current. In any vacuum tube there must be a supply of electrons whose transfer constitutes a current. In the gas tube there must be a small amount of air or other gas whose ionization supplies the electrons. When these electrons are available a suitable potential applied to the tube terminals will cause the electrons to leave the cathode and travel to the anode (anticathode) at high velocity. This stream of electrons is known as the cathode rays. At the target, upon which the stream is focused by virtue of the concave cathode, the electrons are suddenly arrested giving rise to electromagnetic pulses which travel in all directions from the target. These electromagnetic vibrations or waves are the x-rays.

The supply of electrons is obtained in quite a different manner in the two types of tubes. In the case of the Coolidge tube the electrons are liberated from the atoms of the tungsten filament by means of heat (see Chapter IV). In the case of the gas tube the electrons are obtained by a breaking down of the gaseous atoms through ionization, a small amount of gas being purposely left in the tube.

Gas tubes are being employed less and less for therapeutic purposes, nevertheless the student should be acquainted with the ionic and other phenomena of the gas tube.

A simple way to observe some of the phenomena of a gas tube is to obtain a discarded tube of high vacuum and watch the changes that occur as the vacuum is gradually reduced by means of the vacuum control. Let us take such a tube and study these phenomena. Let us suppose that the vacuum is equal to a 7- or 9-inch parallel or alternative spark gap—low atmospheric pressure. The current will pass with difficulty on account of the paucity of electrons. The wall of the tube will fluoresce a pale, cold-green color and x-rays of considerable penetration will be emitted. Now, if a little gas is allowed to enter, by means of the "regulator," the resistance becomes less (spark gap is shorter) the fluorescence is more pronounced and its color changes to a warmer tone—a yellowish-green. The x-rays now emitted are less penetrating. If the vacuum is lowered still more the fluorescence loses its brilliancy and is gradually replaced by an olive-green to dull-bluish radiation, which is possibly due to extremely active ultra-violet light. This radiation is usually first noticed around the cathode and anode and gradually spreads until it replaces the general fluorescence. There are now no x-rays emitted from the tube. In the meantime the parallel spark gap of the exciting apparatus is reduced to a fraction of an inch, indicating that there is very little resistance to the passage of the current. Before the greenish fluorescence disappears a bluish-violet pencil of radiation appears between the cathode and anticathode. It is conical in shape with the base at the cathode. This is the cathode stream or cathode rays. If gas continues to enter the tube both the greenish fluorescence and the cathode rays disappear.

Next, the tube becomes filled with a brilliant, pink-violet radiation which gradually develops into a luminous band of the same color, which extends from the anode to the cathode. This is probably the so-called positive column or canal rays of Goldstein, which is composed of ions carrying a positive charge.

It is usually not possible to reduce the vacuum any lower by means of the "regulator," but if the tube is punctured by an electric spark so that air is allowed to slowly enter, additional phenomena can be observed. The wide positive column becomes very narrow and undulating and finally, as the interior of the tube reaches normal atmospheric pressure, the band breaks into a series of fine, noisy sparks. At the same time the parallel spark gap increases, indicating an increase in resistance.

The proper way to study the phenomena of the gas tube is to observe the varying effects produced by the passage of a high-potential current through an exhaust tube that is being gradually exhausted. In this way one can watch the evolution of the positive column, the negative glow, the Faraday dark space, the cathode dark space, the ultra-violet radiation and finally, the green fluorescence.

Cathode Rays.—The cathode rays, invisible excepting through their power of effecting ionization and fluorescence are, as we have seen, composed of electrons which consist of negative electric charges. The nature of the cathode rays is independent of the size or shape of the cathode and of the material of which it is constructed; also of the kind of residual gas in the tube. The velocity of the cathode rays depends entirely upon and varies with the difference in potential, *i. e.*, the voltage, between the electrodes. A velocity greater than $\frac{1}{3}$ that of light has not been noted. The cathode rays exhibit a certain amount of penetrating power and this penetrability depends upon and varies with the velocity. The rays of highest speed can penetrate only about 2 or 3 mm. of air and about 0.0015 cm. of aluminium. The bulk of the energy of the cathode rays is converted into heat when they strike an obstacle. This accounts for the marked production of heat at the anticathode. Targets made of platinum and even of tungsten with its extremely high melting-point (3000° C.) can be fused and even volatilized in the rare atmosphere of a vacuum tube by these rays.

The cathode rays are powerful ionizers. They excite a pronounced fluorescence in certain substances such as glass, barium platinocyanide, willemite, etc. The greenish fluorescence of the walls of an *x*-ray tube is due to cathode rays which have been "reflected" from the target. They cause soda glass to fluoresce green while lead glass assumes a bluish color. Cathode rays possess powerful photographic action and they are deflected by an electric or magnetic field.

The cathode rays are identical with the beta rays of the radioactive elements. The only apparent difference is one of velocity, so that there naturally follow variations in penetrability and ionizing power. It is

possible that the day will come when cathode rays of great velocity will be obtained by means of modifications of the Lenard tube and that such rays will be employed in the treatment of the more superficial cutaneous diseases. In fact this has already been done by Strebel in two cases of epithelioma.

Positive Rays.—The positive or canal rays are composed of positively charged corpuscles or ions possessing an apparent mass of about that of the hydrogen atom. While they travel at high speed the velocity is considerably less than that of the cathode rays. They possess strong ionizing, fluorescing and photographic qualities. Their penetrating power is very slight, infinitely less than that of the cathode rays. They are reflected by a magnetic field but in the opposite direction from that of the cathode rays. In recent years Sir Joseph Thompson has added a valuable method to gas analysis. It consists of a photographic study of the parabolic paths of the positive rays after a magnetic and an electric deflection. The path of the positive rays composed of hydrogen atoms is distinctly different from the path of the positive rays composed of hydrogen molecules. A new substance of atomic weight 3 has thus been discovered.

Ionics of the Gas Tube.—The production of the canal and cathode rays can be explained on the basis of ionization. A gas tube is either not completely exhausted or a little gas is allowed to enter the tube after complete exhaustion. When a suitable potential is applied to the tube it is assumed that some of the gaseous atoms liberate electrons and positive corpuscles (negative and positive ions) which travelling at high velocity bombard and disintegrate other atoms with the production of additional ions. The positive ions constitute the canal rays which are compelled to travel from anode to cathode by the electrical condition of the interior of the tube. By some it is believed that the canal rays bombard the metal cathode, disintegrate its atoms and liberate electrons thus producing the cathode stream. Others are of the opinion that the negative ions or electrons, liberated by ionization of the gas, collect at the cathode and are then forced to the anode by virtue of the electrical conditions of the tube and the concavity of the cathode. Kaye states that it is the canal rays that cause the positive electrification of the wall of the gas tube and this in turn may attract some of the cathode rays to the periphery of the tube where they give rise to the greenish fluorescence.

A tube containing very little gas (fairly complete vacuum) transmits little current because there is so little ionization. With more gas (lower vacuum) ions are abundant and the gas becomes a good conductor. This process continues until atmospheric pressure is approached when the resistance again increases because ionization does not take place to any considerable degree under these conditions.

The student should clearly differentiate the phenomena of the two types of tubes—gas tube and Coolidge tube. There is no gas in the latter type of tube, therefore there is no ionization. Here, as already

stated, heat causes the tungsten filament of the cathode to liberate electrons and the potential applied to the tube provides the velocity and causes the electrons to travel to the anode. The writer has been asked on many occasions: "Can the Coolidge cathode supply electrons forever?" In answering this question we must call attention to the modern conception of electricity—that it is the passing along of electrons or of a negative charge from one atom to another. While this is an atomic phenomenon it does not necessarily signify that there is an actual conversion from one physical state to another. Electrons can leave the tungsten atom under the influence of heat and of applied potential but the atom gains new electrons from other atoms of the same element or of a different element. In other words, electrons from the atoms of the conductor replace those lost by the tungsten atoms.

ROENTGEN OR X-RAYS.

The *x*-rays, as we have seen, are electromagnetic waves of very short wave lengths. They are produced by the sudden arrest of the electrons of the cathode rays at the anode or target of the *x*-ray tube. They travel in straight lines in all directions with the velocity of light and are not deflected by the influence of a magnetic or electric field. *X*-rays are invisible, they are powerful ionizers, they have a strong photographic action and are capable of provoking a marked fluorescence on certain chemicals such as the platinocyanide of barium. A beam of *x*-rays, like light, is not homogeneous—that is, it is composed of waves of different lengths. As in the case of light it is possible to separate these various wave lengths and to study the characteristics of each individual length. In the case of light we can recognize to a certain degree the various wave lengths by the impression that these different wave lengths make on the eye, namely, the different colors. The wave lengths of the *x*-rays are too short to be appreciated by our senses, therefore they are invisible. On account of the extreme shortness of the waves they cannot be separated in the same manner as can those of light—prism or defraction grating—the finest lines being too coarse for such short waves. But in crystals we have an arrangement of atoms in planes which is the equivalent of an exceedingly fine-lined defraction grating. It is by this means that the *x*-ray spectrum is obtained (Hull, Bragg, Joly, Russ, etc.). One of the chief characteristics of *x*-rays is their ability to penetrate all substances roughly in proportion to the atomic weight or density of the substance. The shorter the wave length the greater is the penetrability. The *x*-ray spectrum, therefore, consists of waves of different length and of different penetrability. The student should keep this fact constantly in mind.

The wave length is governed by the velocity of the electrons of the cathode stream, and by the suddenness and completeness with which the electrons are stopped at the target—and as this velocity depends upon the potential difference between the electrodes it may be said

that the wave length or penetrability of the resulting x-rays depends upon the potential (voltage) applied to the terminals of the roentgen tube.

Even with an unfluctuating voltage where electron speeds would be equal, the x-rays would not be homogeneous—all of the same wave length when the tube is operated on a given potential. Shearer explains the reason by means of a simple illustration (Fig. 1). This figure represents an enormously magnified polished tungsten surface (target). Imagine an electron moving toward the rough surface at *P*. Its speed will be somewhat altered at this impact and it may be deflected to *Q* and then to *R*. During each contact or period of change in velocity, a roentgen ray will be originated. Thus a group of these rays may be started by a single electron. On the other hand direct impact, as at *D*, would set up a wave of greater energy for the same initial electron speed than in the previous case. The irregularities of a highly polished metal surface are doubtless much greater than those shown in comparison with the diameter of an electron.

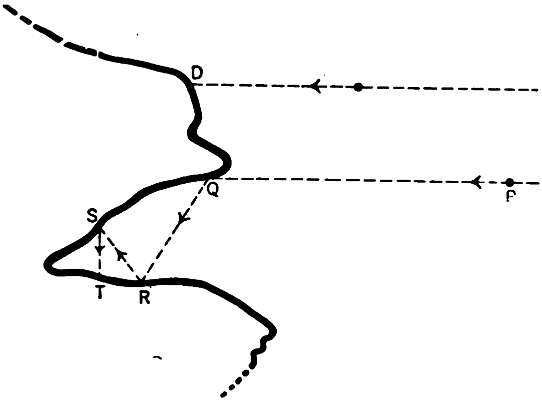

Fig. 1.—The possible course of an electron striking a polished metal target and deflected several times before coming to rest; path P–Q–R–S, etc. A different wave length may be originated at each impact. Also possible central impact at D giving a single wave length. (Shearer.)

It should be obvious from the foregoing that the nature and quantity of the radiation emitted from a given type of tube is absolutely fixed by the number of electrons used per second and their striking speed. The number of electrons is estimated by measuring the amount of current by means of a milliammeter while the fall of potential through which the electrons must fall in order to acquire the velocity is measured by voltmeters or alternative spark gaps. These questions will be discussed in detail in subsequent chapters.

It is difficult for the student to obtain any conception by process of comparison or visualization of the size of a short electromagnetic wave such, for instance, as that of the x-rays. For this purpose Shearer

states that "it is customary in physics to select such units of measurement as will avoid the use of very small fractions or of very large numbers. Thus the micron, or $\frac{1}{1000}$ millimeter, is used as a unit in microscopy. An average hair is about 20 microns in diameter or $\frac{20}{1000}$ mm., or $\frac{2}{1000}$ cm. In measuring wave lengths of light the angström or $\frac{1}{100000000}$ cm. is usually chosen as a unit. The wave length of yellow light from sodium vapor is about 6000 of these units, while roentgen-ray wave lengths would be expressed by fractions of an angström. Thus we have the diameter of a hair, 0.002 cm.; wave length of yellow light, 0.0006 cm.; medium roentgen-ray wave length, 0.000000005 cm. Multiplying these fractions by 10 nine times, we have: roentgen-ray wave length, 5; yellow light wave length, 60,000; diameter of hair, 2,000,000. So that the hair could contain 400,000 of these roentgen-ray wave lengths in its own diameter. It is, then, clear that these waves are of exceeding 'fineness of grain' if we may use a common term. The distance between atoms in crystals of metals is from 2 to 4 angströms, so that such atoms are separated by a distance equal to several wave lengths of roentgen rays, such as are commonly used. It may readily be seen how the behavior of such waves would be differently affected by matter than would that of long ones."

In the evolution of physics and medicine the word "ray" has been used to denote two dissimilar physical phenomena and this has occasioned no little confusion in the mind of the student. As will be explained later in this chapter, when an atom of a radioactive element breaks down small particles of definite size and properties are projected at high velocities—electrons and alpha particles. The former are called beta particles or beta rays; the latter, alpha rays. They are concrete entities and may be counted and studied as individuals. Again as Shearer says, "we use the term ray to define the path along which some wave-like disturbance travels as in the case of light waves, heat rays, roentgen rays and gamma rays, where no transfer of matter is involved." Sound waves are produced by the vibration of a tense string which in turn becomes a source of waves transmitted by the air. Light and roentgen rays and gamma rays are electromagnetic waves produced by a disturbance in the electrical components of atoms. These rays will travel through a vacuum and as it is inconceivable that there can be a wave without some transmitting medium physicists have devised the hypothetical substance ether.

Secondary Radiations.—As demonstrated by Sagnac in 1897, when *x*-rays come in contact with any substance, new or secondary radiations are emitted. It was not, however, until 1911, when Barkla and Sadler published the complete results of their investigations, that we gained a very clear conception of these secondary rays. Even now there is considerable controversy and with each addition to our knowledge the subject becomes more complicated. The term secondary rays has been used to designate at least three different things: (1) Roentgen rays

coming from parts of the tube other than the focal spot on the target. As pointed out by Shearer these might be termed parasitic rays. (2) Scattered rays. (3) True secondary rays.

Scattered Rays.—Scattered rays consist of a scattering of some of the primary rays by material through which they pass. They are not, therefore, secondary in character. Kaye likens the phenomenon to the diffusion of light by a fog. Shearer states that "atoms of matter reflect slightly roentgen rays just as particles of dust or mist will reflect light. This results in a slight diffuse scattering of the initial beam without other change. If we could secure a surface made up of a closely packed layer of completely reflecting atoms we would have an *x*-ray mirror. As there are no such atoms or any surface of such smoothness and compactness we have only scattering." The scattering is noticed both in organic and inorganic substances and at all depths. In fact the thicker the material the more abundant are the scattered rays. They are most numerous when the atomic weight of the material is either very low or very high. Inasmuch as most of the elements composing human tissues are of rather low specific gravity the scattered rays are voluminous when, for instance, an intense beam of primary rays is passed through a thick abdomen. And this is one of the causes of fogging and lack of definition of roentgenograms of the abdomen.

Characteristic Rays.—The characteristic, monochromatic or homogeneous *x*-rays are truly secondary in origin. When a primary beam of *x*-rays strikes a metal or other substance, homogeneous rays of definite quality are emitted. These characteristic rays are different for each element; in other words, their character depends upon the metal or element regardless of the character or quality of the primary *x*-rays. No characteristic rays are produced, however, unless the primary rays are more penetrating than the characteristic rays from the substance upon which the primary rays are acting. Also, the intensity of this secondary radiation is in direct proportion to the intensity of the primary rays. The characteristic rays from a heavy substance can excite tertiary characteristic rays from a lighter element but not from a heavier one. In general the penetrability of the characteristic rays increases with the atomic weight of the element. When the primary rays pass through a thin sheet of pervious metal the characteristic rays are emitted from both the proximal and distal surfaces. An explanation of the origin of characteristic secondary rays will be given when discussing the corpuscular secondary rays.

The fact that the characteristic rays are homogeneous has been of great help to experimental physicists for it permits a study of homogeneous rays of any quality. Obviously this would be exceedingly difficult in the case of the heterogeneous primary *x*-rays. Also, the characteristic rays are important in roentgen therapy because, especially in deep therapy, filters are employed to protect the skin from the "soft" or easily absorbed rays (long wave lengths). It is obvious that

if a filter, composed of material from which "soft" characteristic rays are emitted, were employed for this purpose, one would substitute "soft" secondary for "soft" primary rays.

Characteristic secondary rays can be directly produced; that is, they can be excited by cathode rays of suitable velocity as well as by *x*-rays. It is in this manner that characteristic rays from the metal composing the target of the roentgen tube are formed within the tube and become a part of the heterogeneous bundle of roentgen rays.

It has been found by Barkla that in many instances two kinds of homogeneous rays are emitted by an element: One, the more penetrating of the two, is termed the K rays—the other, the L rays. In the case of some elements only one type has been discovered; in others, both; in still others, neither. It is suspected, however, that most if not all elements will be found capable of generating both types under suitable conditions, and it is anticipated that rays other than the K and L rays will be discovered in time.

Corpuscular Rays.—The secondary corpuscular rays emitted by a substance may be the result of the primary, scattered or characteristic rays. The corpuscular rays are negatively charged electrons apparently identical with the cathode rays of the *x*-ray tube and the beta rays of the radioactive elements. It has been determined that both the characteristic and the corpuscular rays from an element are the same whether the element is combined or in the pure state. Furthermore, there is a quantitative or numerical relationship between these two types of radiation—where one is abundant, so is the other. In other words, through the influence of the primary *x*-rays, by a process similar to ionization, an atom loses one or more of its electrons—these are the corpuscular rays. The starting or stopping of these electrons causes electromagnetic pulses—the characteristic rays. In turn the secondary characteristic rays may cause the production of new corpuscular rays. In this way tertiary corpuscular and characteristic rays may be produced and so on.

As will be seen when the question of the biologic action of the various radiations is discussed, ionization may play an important role in the therapeutics of these agents. Bragg's theory that ionization or at least most of it is due, not to the primary radiations, but to the beta rays caused by them, has been confirmed by the experiments of Beatty, Barkla and Philpot and Wilson. If this theory is correct then, as has been pointed out by several investigators, it may be that the therapeutic or biologic effect of the *x*-rays is due to the action of the beta rays formed in the tissues by the passage of the *x*-rays through such tissues. In other words, that the therapeutic power of the *x*-rays or gamma rays lies in the ability of these agents to give rise to beta or cathode rays in the deeper tissues. As pointed out by Colwell and Russ, "the tissues of the body consist for the most part of substances which contain the light elements, hydrogen, carbon, nitrogen and oxygen. Now it is just these and others of the light elements from which homogeneous

secondary *x*-rays have not yet been obtained, but which exert some scattering action upon a primary beam. If there are such homogeneous rays, it is probable that they are of a very "soft" type.

"The ionizing action of the *x*-rays is one of their most striking features and occurs in liquids as well as gases: but how far the biological effects are the result of such ionization remains for subsequent work to decide. Now that some of the fundamental properties of secondary *x*-rays are known, it is highly probable that efforts may be directed toward their use." In this connection a glance at Chart 1 will show that calcium and iron both emit "soft" secondary rays and iron especially is fairly abundant in tissues rich in blood. It is thought that when characteristic and corpuscular rays are produced positive corpuscles are released from the atom. These have been termed secondary alpha rays.

Element.		Thickness of aluminium to absorb one-half.		Thickness of water to absorb one-half, number approximate.	
		Series K. millimeter.	Series L. millimeter.	Series K. millimeter.	Series L. millimeter.
Calcium . . .	12	0.006	....	0.08	
Iron	56	0.028	....	0.4	
Copper . . .	64	0.052	....	0.7	
Selenium .	79	0.13	....	2.0	
Strontium . .	88	0.27	....	4.0	
Silver . . .	108	1.0	0.0036	14.0	0.05
Antimony . .	120	2.1	0.006	30.0	0.08
Barium . . .	137	3.0	0.01	45.0	0.15
Cerium . . .	140	4.0	....	60.0	
Gold . . .	197	....	0.10	....	1.5
Bismuth . . .	208	....	0.13	....	2.0

CHART 1.—Absorbability of homogeneous secondary characteristic *x*-rays.[1]

Reduction of Intensity—*Absorption.*—*X*-rays are reduced in intensity when they pass into or through various materials. Before the discovery of the method of spectral analysis (separation and study of individual wave length) all our information relative to penetration and absorption was derived from more or less uncertain measurements of absorption. The following explanation of the phenomena of absorption is taken verbatim from Shearer.

"The term absorption is used to denote a simple reduction in wave energy due to some action on the material through which the wave moves. Thus, if we pass a beam of light into clear water there will be a loss of illuminating power not explained by reduction due to increased distance from the source. This results in a rise in the temperature of the water showing a transformation of a portion of the energy of short light waves into heat. Again, loss of light might result in chemical

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[1] After Colwell and Russ, p. 15.

action. So in the case of roentgen rays, if in Fig. 2 the energy passing through *I J K L* is less than that passing *A B C D* we say there has been absorption in the intervening material. It is not so easy to say just what form the transformed energy has taken in this case, but a very small amount of heat is produced and ionization, electrochemical action or the production of long wave light rays in the absorbing body must account for the remainder.

"As in the case of light, absorption depends on the material traversed and for a given material is dependent on the wave lengths received.

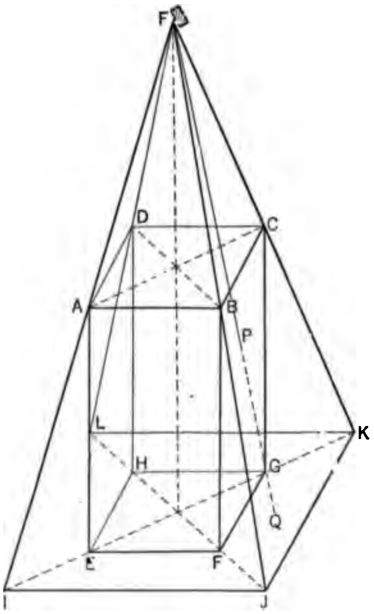

Fig. 2.—F, focal spot on target; A B C D, an area receiving radiation; I J K L would receive the same radiation at the greater distance from F that A B C D receives at the nearer. Hence an equal area at the greater distance receives less, *i. e.*, E F G H receives less radiation than A B C D. Note that each area of the rectangular prism A G, as we go down, receives less radiation because rays entering the prism above pass out through its lateral walls. As the target is moved farther away the rays become more nearly parallel to the edges A E, and less radiation leaves through the sides of the prism. (Shearer.)

One of the most striking characteristics of the roentgen and gamma rays is their penetrating power, *i. e.*, their relatively slight absorption, many substances highly opaque to light or heat showing extreme transparency. Also this is found to vary according to the voltage (spark gap) at which the tube is operated. The term penetration was used to describe roughly this general quality of the radiation and has proved a rather unfortunate concept. For while increased spark gap does raise the 'penetration' by adding shorter and less easily absorbed waves, it also greatly increases the amount of radiation per milliampère,

and after we reach a moderate gap the increase of 'penetration' is relatively slight.

"If we first consider a single wave length for the sake of simplicity we may state the known facts as to absorption: (1) The intensity is reduced in passing through a given thickness of material nearly in proportion to the physical density of the material. (Some variations are noted and 'scattering' must also be considered.) (2) If at the first surface of a layer of a given thickness the intensity is Q_1 and at the distal surface it is Q_2, then the quantity $\frac{Q_1-Q_2}{Q_1}$ represents the percentage absorbed in the layer. (3) The next layer of like thickness will absorb the same fraction of what its proximal surface receives, and this will be true for each layer in succession (observe the limitation to a single wave length).

"Thus, if a layer 1 mm. thick of a given material will absorb 0.04 of the radiation of a given wave length received when 100 arbitrary units fall on the surface of the block of this material, the amount passing successive layers each 1 mm. think will be:

First surface	100.00
1 mm. below	96.00
2 mm.	92.16
3 mm.	88.47
4 mm.	84.93
5 mm.	81.53

"Each number being obtained by multiplying the preceding by 0.96. The amounts absorbed by the several millimeter layers are:

1	4.00 units
2	3.84 "
3	3.69 "
4	3.54 "
5	3.40 "

"Assuming that the source is so far away that we may neglect an increase of distance up to 5 mm.

"For this same absorbing material and a longer wave length the first millimeter may remove 0.1 of the surface radiation. Then the series for 100 units on the proximal surface will be:

First surface	100.00
1 mm. below	90.00
2 mm. below	81.00
3 mm. below	72.9
4 mm. below	65.61
5 mm. below	59.05
Left in first mm.	10.00
Left in second mm.	9.00
Left in third mm.	8.01
Left in fourth mm.	7.29
Left in fifth mm.	6.56

"Observe now that 5 mm. in the first case have absorbed only 18.47 units, while in the latter 40.95 units are absorbed. Also we must note

that the ratio of absorption in the first millimeter to that in the fifth is quite different, 4 : 3.4 and 10 : 6.56 or 1.17 and 1.52 in the two cases.

"We see then that the higher the rate of absorption of the material for the wave length considered, the more the first layers absorb and the greater the difference between that absorbed in the first millimeter and that in any given millimeter below the first.

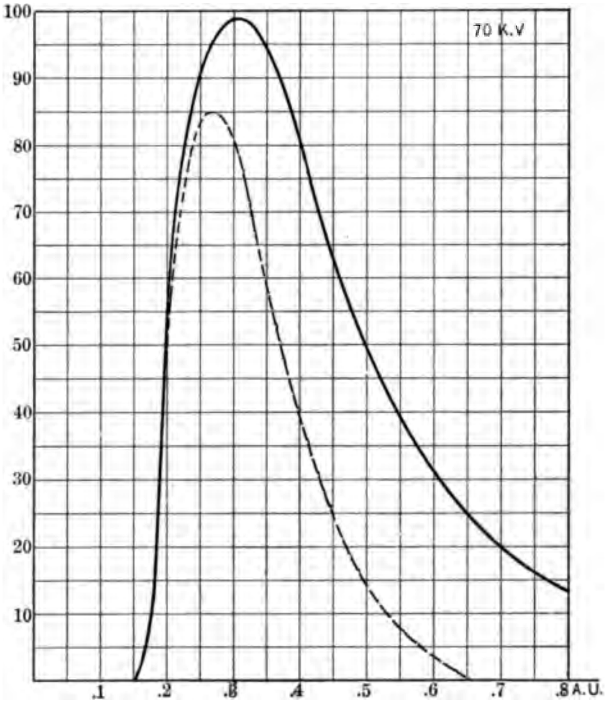

Chart 2.—Solid line A shows roentgen-ray intensity of various wave lengths for a tungsten target tube operated at 70,000 volts. The broken line shows what survives after passing through 3 mm. of aluminium. About 50 per cent. of the 70,000 volt radiation is absorbed by 3 mm. of aluminium; measurements by Dr. Hull. (Shearer.)

"The actual output of the tube always contains a great variety of wave lengths, and each wave length has its own rate of absorption, but the rate is always less for short than for long waves. Chart 2 shows the effect of 3 mm. of aluminium on the radiation at 70,000 volts (about a 6-inch gap) as measured by Hull. We see that no rays of wave length exceeding 0.7 x 10^{-8} get through. Also the intensity of wave length 0.5 x 10^{-8} is reduced from 50 units to 14, 0.4 x 10^{-8} from 100 to 80. Or the transmissions in percentages of initial quantities are:

Wave length.	Percentage.
0.5 by 10^{-8}	28
0.4 by 10^{-8}	50
0.3 by 10^{-8}	80

The percentages absorbed are:

Wave length.	Percentage.
0.5 by 10^{-8}	72
0.4 by 10^{-8}	50
0.3 by 10^{-8}	20

"The 3 cm. of aluminium absorb for this voltage very nearly one-half of the total radiation, but take their toll largely from the longer wave lengths.

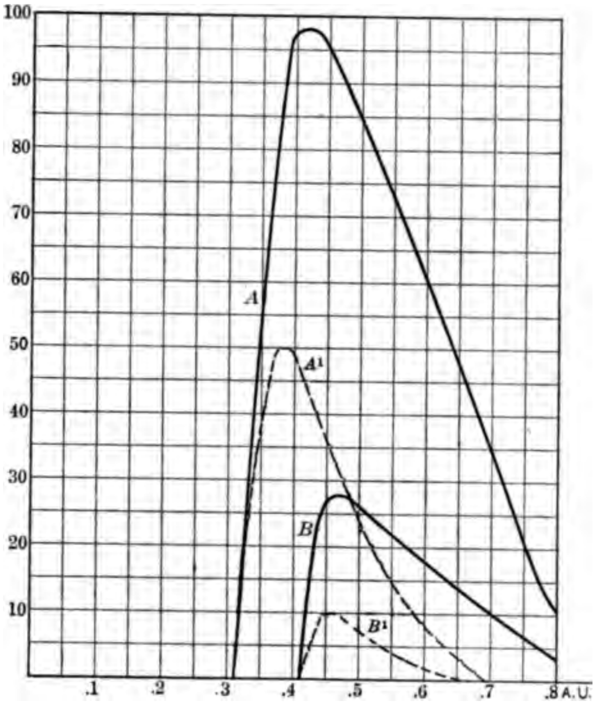

Chart 3.—Curve A shows amount of radiation at 40,000 volts unfiltered. A^1 shows reduction by using 3 mm. of aluminium as a filter. B and B^1 show the same for 30,000 volts. (Shearer.)

"To emphasize this matter still further, consider Hull's spectrum curves at 40,000 volts and at 30,000 volts and apply the same percentage reduction by 3 mm. of aluminium for the same lengths as in his 70,000 volt curve as far as they are present at these voltages. Chart 3 shows the results. The area under *A* is proportional to the unfiltered radiation, that under *A'* to the filtered radiation for 40,000 volts. *B* and *B'* are the same for 30,000.

"We may definitely say from these results that: (1) The total radiation from a tube operated at low voltage is less than for one operated at the same current at high voltage. (2) The energy from the low voltage tube is more easily absorbed. (3) The proportion absorbed in the first layers is much greater at low voltage than at high.

"But the therapeutist may well be excused if he asks, 'What has the results of absorption in aluminium to do with the biologic action of these rays?' The answer is plain if we assume (what seems almost an axiom to the physicist) that the biologic action is entirely due to that part of the radiation actually absorbed. This granted, we may at once call attention to the fact that the general distribution of absorbed radiation in successive layers for a given wave length is similar for all substances, differing only in the thickness of layer required to absorb a specific percentage. Thus, a thickness of human flesh could be found absorbing a given wave length in nearly the same ratio as 1, 2 or 3 mm. of aluminium. In other words, the distribution of the absorbed radiation will be governed by the same general considerations as given above, but it will require greater thicknesses of flesh than of aluminium to absorb a given percentage.

"The term filter has been applied to any material used between the tube and the patient's skin. The purpose of the filter is to remove a large part of the radiation that would otherwise be absorbed by the superficial layers of flesh. They are necessary and important for the treatment of deep-seated lesions. It may also be noted that as the rays have passed through the glass wall of the tube they are already in part filtered. On account of the low density of air, both its absorption and its filtering action may be neglected in practice."

THE RADIOACTIVE ELEMENTS.

By radioactivity is meant the property of an element of spontaneously emitting radiations that are photographically active and that will discharge an electroscope. Of these radioactive bodies there are at present about thirty known to science. The best known radioactive elements are uranium, thorium, actinium, radium and polonium. While our interest centers mainly in radium it is advisable to consider briefly the more important radio-elements. This can be done by utilizing a series of excellent charts or tables borrowed from Colwell and Russ.

By activity is meant the intensity of the electrical, ionizing or photographic effect of the radiation from an element as compared with that of a standard substance, usually uranium. The activity of a substance is inversely proportional to its time-period. The time-period is the time required for a radioactive body to lose one-half of its initial activity. As explained by Colwell and Russ "a body with a time-period of one minute meaning, thereby, that one-half of it in this time will have been transformed into some other substance, will be 60 times as active as a body with a time period of an hour. By this is not meant that the first body would necessarily give effects 60 times as large as an equal weight of the second body, for the radiation emitted by the two bodies might be of two different types; nevertheless, the term activity is associated with the time-period in the manner indicated." The time-periods of the various radioactive elements differ enormously.

The primary radioactive elements, such as uranium and thorium, are comparatively stable and have lives of a thousand million years. Radium, on the other hand, a product of the decay of uranium, has a period of only about seventeen hundred years. At the other extreme there is a member of the thorium series with a period of less than a millionth of a second (Colwell and Russ).

Very few of the radioactive elements have been obtained in the pure state so that the atomic weight of most of them is unknown. Those that have been determined are very high. All the bodies formed in the transformation of the radioactive elements possess elementary characteristics and they are considered to be elements.

Uranium.—This primary radioactive element is the parent of radium, but in the transformation there are formed a series of intermediary products as shown by Chart 4. The chart also includes the time-period for each substance and the radiation emitted therefrom.

Substance.	Time to decay to half value.	Radiation emitted.
Uranium (1 and 2)	5 x 10.9 years	Alpha.
Uranium X (1 and 2)	24.6 days	Beta and gamma.
Ionium	3.5 x 10.5 years	Alpha.
Radium	1690 years	Alpha, beta and gamma (beta and gamma very weak).

CHART 4.—Uranium series.[1]

"Uranium probably consists of two bodies—uranium 1 and uranium 2—but they are not separable. Uranium Y is a lateral product of one of these bodies and is not included in the table of direct descent." Uranium X in recent years also has been found to consist of two bodies.

It will be seen that in the decay of uranium, radium is the end-product and that during this transformation uranium X is formed from which beta and gamma rays are obtained. No uranium emanation has yet been discovered. The activity of uranium is about two million times less than radium.

Radium.—This is the most active element known. It possesses many of the chemical characteristics of barium. Its atomic weight is 225 and its spectrum is similar to the spectra of the alkaline earths. Chart 5 illustrates the transformation of radium.

Substance.	Time to decay to one-half.	Radiation emitted.
Radium	1690 years	Alpha, beta and gamma (beta and gamma very weak).
Radium emanation	3.85 days	Alpha.
Radium A	3.0 minutes	Alpha.
Radium B	26.8 minutes	Beta and gamma.
Radium C (complex, probably consisting of three bodies)	19.5 minutes	Alpha, beta and gamma.
Radium D	16.5 years	Beta.
Radium E	5.0 days	Beta and gamma (gamma very feeble).
Radium F—Polonium	136.0 days	Alpha and gamma.
Lead		

CHART 5.—Radium series.[2]

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[1] After Colwell and Russ, p. 39.

[2] Ibid., p. 40.

Actinium.—This element is about as radioactive as uranium. It is thought to be derived from one of the lateral products of the uranium series.

Substance.	Time to decay to one-half.	Radiation emitted.
Actinium	Unknown.	
Radio-actinium	19.5 days	Alpha and beta (weak).
Actinium X	10.2 days	Alpha.
Actinium emanation	3.9 days	Alpha.
Actinium A	0.002 second	Alpha.
Actinium B	36.0 minutes	Beta.
Actinium C (probably complex)	2.15 minutes	Alpha.
Actinium D	4.71 minutes	Beta and gamma.

Chart 6.—Actinium series.[1]

Thorium.—Thorium is interesting to the therapeutist because its use has been advocated in place of radium. It is more easily obtained and, therefore, cheaper than the latter, but it is much less radioactive than radium. Weight for weight thorium compounds have about the same radioactivity as the corresponding compounds of uranium. In recent years, however, preparations of mesothorium have been obtained that approach in activity and quantity that of radium. On the other hand, the life of mesothorium is comparatively short, having a time period of about five and a half years. In this connection, however, Colwell and Russ state that "the diminution in the beta and gamma ray intensity of an originally pure mesothorium preparation does not begin for ten years, owing to an intermediate increase in the activity. At the end of the next ten years the activity will be reduced to 50 per cent. of that of the original preparation."

Substance.	Time to decay to one-half.	Radiation emitted.
Thorium	1.3 x 10 10 years	Alpha.
Mesothorium 1	5.5 years	
Mesothorium 2	6.2 hours	Beta and gamma.
Radiothorium	2.0 years	Alpha.
Thorium X	3.65 days	Alpha.
Thorium emanation	54 seconds	Alpha.
Thorium A	0.14 second	Alpha.
Thorium B	10.6 hours	Alpha.
Thorium C (complex, probably three bodies	1.0 hour	Beta and gamma.
Thorium D	3.1 minutes	Beta and gamma.
Bismuth?		

Chart 7.—Thorium series.[2]

As shown in Chart 7, thorium X emits an emanation which has a time-period of only fifty-four seconds as compared with the time-period of nearly four days for the radium emanation. The thorium emanation is not, therefore, of much practical value unless, as pointed out by Colwell and Russ, a continuous bubbling of a stream of air through a thorium solution were provided for, when the emanation would be formed rapidly enough to provide for the rapid decay.

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[1] After Colwell and Russ, p. 41.

[2] Ibid., p. 42.

Thorium has not been employed for therapeutic purposes in this country as extensively as in Europe, but the future may possibly see a change in this respect. Very extensive deposits of ore with a rich thorium content have been discovered in Brazil and as thorium is extensively employed in the manufacture of numerous commercial products the element may yet find favor in the eyes of the medical profession.

As will be seen from the foregoing the atoms of the radioactive elements are inherently unstable. Some unknown force causes or allows a spontaneous rupture of the atom with the liberation of a beta or an alpha particle. The atom has been lowered in weight and represents a new element. In the case of thorium, for instance, an alpha particle escapes; the remaining atom is one of mesothorium. From this element beta particles escape with the formation of radiothorium, then in turn we have thorium X, the gaseous element or emanation, etc. Finally an atom with little or no radioactivity and with increased stability is produced which, in the case of thorium, is probably bismuth, while the end-stage of the transformation of radium is probably lead. Thus we have a natural process consisting of the transformation of heavy elements into those of lighter weight, which is just the reverse of the alchemist's dream. This process of transformation represents and is the basis of Rutherford and Soddy's disintegration theory.

Occurrence of Radioactive Substances in Nature.—Practically nothing is known relative to the formation of the primary radioactive elements. Rutherford suggests that these heavy atoms are constructed of units composed of helium and hydrogen. It will be remembered that helium is always found in the presence of the radioactive substances, that it is an inert gas, that its atom is an alpha particle and that this atom simulates in several particulars the hydrogen atom. Furthermore, helium is known to exist in the sun. Barrel has suggested that the primary radio-elements are being constantly produced in the interior of the earth.

Radioactive substances are widely distributed in nature. The largest amounts are found in the pitchblende (uraninite) deposits of Bohemia. In a ton of this Bohemian (Joachimsthal) pitchblende, which contains about 50 per cent. of uranium, the yield of radium is roughly about .17 gm. Pitchblende is found in several countries; in the United States a deposit with a good radium yield is located in Colorado but it occurs in small quantities only. Carnotite is found in Colorado and Utah. This mineral is not very rich in radium but it is found in large quantities. In Brazil are found inexhaustible deposits of thorium-containing ore.

Traces of radioactivity have been noted in sea-water, river waters, spring waters, volcanic and other rocks, earth, air, etc. As a matter of fact there are few places where a trace of radioactivity cannot be demonstrated. A minute trace is found in organic tissues. This last

factor has led to the interesting suggestion that malignant tissues might be less radioactive than normal tissue but this has not been found to be so. It is evident that we live in a medium of radioactivity but there is as yet no conclusive evidence to support the belief that radioactivity as we understand it, is directly necessary to life.

On account of the radioactive content (usually emanation) of certain natural springs, these waters have been extensively advocated in the treatment of various chronic diseases. Some of these waters are fairly potent, but Colwell and Russ, in reviewing some analyses state "there was, however, no obvious connection between the amount of emanation found and the potency of such waters from the point of view of spa treatment, some of the most celebrated spas having among the lowest recorded emanation." Chart 8 gives the radioactivity of a few spring waters.

Spring waters.	Millicuries per million liters.
Bath	1.73
King's Well water	1.19
Cross Bath waters	1.70
Hetling Bath water	33.65
King's Well gas	
Buxton	0.83
Hospital Natural Bath water	0.83
Crescent Pump-Room water	1.10
Gentlemen's Natural Baths water	7.7–8.5
	Curies per liter.
Karlsbad, Bohemia, Eisenquelle	28.4×10^{-9}
Karlsbad, Bohemia, Muhlbrunnen	48.4×10^{-9}
Marienbad, Bohemia, Nebenquelle	42.5×10^{-9}
Teplitz-Schönan, Bohemia, Steinbadquelle	41.5×10^{-9}
Gasteni, Austria, Grabenbäckerquelle	80.7×10^{-9}
Hot Springs, Arkansas, U. S. A., Twin Spring	3.0×10^{-9}
Hot Springs, Arkansas, U. S. A., Imperial Spring	9.0×10^{-9}

CHART 8.—Radium emanation in spring waters.

Radiations from Radioactive Substances.—The radiations emitted from the radioactive bodies are three in number—alpha, beta and gamma rays. A study of the preceding charts will show that every substance which emits gamma radiation also gives off beta particles but the converse is not always true. When an atom breaks down and an electron is liberated it will give rise to electromagnetic waves (gamma rays) providing the electron starts out at a sufficiently high velocity.

Alpha Rays.—The alpha rays or particles are actually helium atoms and carry two positive units of electricity. Their mass is therefore four times that of a hydrogen atom. They travel at high velocity, the speed depending upon the substance from which they are derived, but from any one substance the alpha particles all have the same velocity. The average velocity is about $\frac{1}{10}$ that of light (18,600 miles per second). The penetrability of the alpha rays is very slight and depends upon the velocity. The greatest range in the air for these rays is 8.6 cm. and they can be entirely absorbed by a sheet of ordinary

writing paper or 0.006 cm. of aluminium. They possess powerful fluorescent, photographic and ionizing powers but, of course, the last, while intense, is very superficial—a fact of therapeutic importance. The alpha rays are deflected in the opposite direction from the beta rays in a magnetic field.

Beta Rays.—These rays consist of negatively charged particles—electrons. With the exception of velocity they are identical with the cathode rays of the *x*-ray tube. They travel at high velocity and this velocity depends upon the substance from which they are emitted. But unlike the alpha rays, the beta rays from any one particular substance are heterogeneous—that is, there is a variety of speeds. The beta rays have a much greater velocity than do the cathode rays. The speed of the latter ranges from $\frac{1}{10}$ to $\frac{1}{3}$ that of light, while some of the former approach very closely the velocity of light.

Beta rays possess strong photographic, fluorescent and ionizing powers, but to a less marked degree than the alpha rays. The ionizing effect, however, is carried deeper into the tissues because the beta rays are capable of considerable penetration, the penetrability depending upon the velocity. The "soft" beta rays are absorbed by 0.1 mm. of aluminium; from 1 to 5 mm. of aluminium will absorb most of them. To prevent the passage of all the beta rays of high velocity it would require 10 mm. of aluminium or 2 mm. of lead (Failla).

Colwell and Russ find that unscreened beta rays are reduced to about $\frac{1}{10}$ of their initial value after passing through 1 mm. of aluminium. If the rays are first screened by 1½ mm. of aluminium the value is reduced to about 47 per cent. of the initial value. Also that the initial value is reduced to 26 per cent. after passing through 4½ mm. of human tissue. It is obvious, therefore, that beta rays are of therapeutic value only in very superficial conditions.

Gamma Rays.—Gamma rays, with the exception of wave length, are identical with the *x*-rays. Gamma rays from any substance are heterogeneous—composed of different wave lengths. This range of wave lengths is greater than in the case of the *x*-rays. The longest waves of the latter are stopped by the glass wall of the tube. This is not so in the case of the gamma rays unless the radioactive substance is placed in a glass tube or is compelled to pass through some other filtering medium. The shortest gamma rays are much shorter than the shortest *x*-rays, therefore gamma rays are the more penetrating. The most penetrating gamma rays are about twice as penetrating as the most penetrating *x*-rays yet produced. Practically 10 cm. of lead will stop the gamma rays, but with 50 millicuries of radium emanation the presence of gamma rays can be detected electrically (ionization) behind a lead screen 25 cm. thick (Failla).

Gamma rays possess strong ionizing, photographic and fluorescent properties but to a much less degree than do the alpha and beta rays.

What has been said relative to absorption of *x*-rays may be repeated for the gamma rays. Absorption of *x*-rays, gamma rays, cathode rays,

and beta rays seems to be an atomic phenomenon. This assertion is based on the fact that absorption is independent of the chemical combination of the atoms as shown by the fact that if a beam of radiation is passed through a layer of silver nitrate solution and then through a layer of hydrochloric acid, the absorption will be the same as though the two solutions comprised a single mixture and even though silver chloride were precipitated in the process (Failla).

Absorption of "hard" beta rays follows fairly closely an exponential law; that is, an equal thickness of the same material absorbs the same fractional amount of a hypothetical incident beam of beta rays. Thus if initial intensity is reduced to half value by 1 mm. of aluminum, 2 mm. of aluminum will reduce the initial value to one-fourth. This is true with both *x*-rays and gamma rays of any given wave length, as for instance, when gamma rays are first filtered through several millimeters of lead to remove all but the very short wave lengths.

Practical Comparison of Penetrability.—The student must learn to think of *x*-rays and gamma rays in terms of wave lengths. The terms hard, medium and soft, to designate rays of great, moderate and slight penetrability, have been employed for years and will probably continue to be so used. There is no objection to this so long as it is clearly understood that penetrability in the case of *x*-rays and gamma rays, ignoring density of material, depends entirely on the wave lengths, short wave lengths being more penetrating than are long wave lengths. The penetrability of beta rays and alpha rays (particles of matter) depends upon velocity. The terms hard and soft are also used in the case of beta rays.

Gamma rays, as we have seen, are more penetrating than are *x*-rays. It must not be forgotten, however, that "soft" gamma rays are less penetrating than are "hard" or "medium" *x*-rays. *X*-rays are more penetrating than beta rays but "hard" beta rays are more penetrating than are "soft" *x*-rays. Alpha rays are stopped so easily that they can penetrate not more than .089 mm. of human tissue (Colwell and Russ). It is obvious, therefore, that they could hardly penetrate the thin epidermis of the healthy skin or a slightly thickened horny layer.

These same authors show, by means of an interesting table that we herewith reproduce (Chart 9), the penetrating powers of the beta rays in epithelial tissue.

Thickness of tissue.	Intensity.
0	100.0
0.65 mm.	85.5
1.95 mm.	62.0
3.25 mm.	43.0
4.55 mm.	26.3
1.00 cm.	6.2

CHART 9.—Unscreened.[1]

The numbers in this table show that the intensity of the "hard" beta rays would be reduced to about 6 per cent. of their initial value

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[1] After Colwell and Russ, p. 58.

after traversing 1 cm. of tissue. The thickness of the entire skin (epidermis and derma) ranges in health between 2 and 4 mm., in a few locations being perhaps 6 mm. thick, while in disease it may be increased to 1 or 2 cm. It will be obvious, therefore, that in employing beta rays for therapeutic purposes one must take into consideration the exact anatomical position of the disease and the depth of the tissue to be treated. The percentage of absorption will be less, of course, for the very superficial tissues if the beta rays are first screened. In this manner it becomes possible to affect the tissues to a depth of several centimeters.

Secondary Radiations.—When gamma rays strike an obstacle beta rays are produced. The intensity of these secondary beta rays increases with the intensity of the primary gamma rays and also with the density of the material upon which they impinge. A primary beam of beta rays, when stopped by a metal or other substance, gives rise to gamma rays, the intensity and penetrability of these secondary gamma rays depending roughly on the intensity of the primary beta rays and the atomic weight of the interposed substance. The secondary gamma rays can give rise to tertiary beta rays and these in turn to gamma rays and so on. It is even thought that the alpha rays when arrested give rise to exceedingly "soft" beta and gamma rays. It will be seen from the foregoing that the secondary rays from the radioactive elements are analogous to the secondary *x*-rays. Both gamma and beta rays are "scattered," just as are the *x*-rays.

Emanation.—In the preceding pages we have seen that several of the radioactive elements emit an emanation and that the gaseous substance is simply one of a series of products formed in the process of decay. An emanation is an unstable and inert gaseous element of high atomic weight (radium emanation has an atomic weight of about 222). Emanations are short lived (time period of radium emanation is about four days). When the unstable atom disintegrates it does so by emitting an alpha particle. The atom then becomes one of radium A.

Radium emanation is powerfully radioactive, the gamma and beta rays being generated in the process of disintegration of radium C, D and E. It is absorbed by water, the solutions being employed for ingestion and injection. Sealed glass capillary tubes containing emanation are inserted into cavities. These tubes are so small that they can be placed in aspirating needles which in turn are inserted into malignant growths. As will be shown in a subsequent chapter, emanation therapy has reached a high degree of perfection and is rapidly superseding the older method of employing radium directly, especially for deep therapy in large institutions.

Active Deposits.—When emanation is allowed to enter a vessel a radioactive substance is deposited on the walls of the vessel. This is known as the active deposit and it consists of a number of rapidly changing, powerful, radioactive bodies. As will be seen by a glance at Chart 5, the radium emanation emits alpha particles and becomes

radium A with a time-period of three minutes. This, in turn, loses alpha particles and is thereby converted into radium B which has a time-period of about twenty-seven minutes; and then radium C (time-period 19.5 minutes) is formed, etc. These three bodies—radium A, B and C, constitute the "radium active deposit of quick change," which emits, of course, alpha, beta and gamma rays. This deposit is very active and it is possible to place very intense deposits in metallic needles and on metallic plates and such applicators can be utilized for therapeutic purposes. The "active deposit of quick change" is spontaneously converted into radium D which is comparatively inactive and which has a rather long time period (sixteen years).

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CHAPTER III.

X-RAY APPARATUS.

Current Supply.—By direct current (D.C.) is meant a flow of electricity in one direction only. Dry cells, wet cells, accumulators (storage batteries) static machines and D.C. dynamos deliver direct current. A current may be pulsating or intermittent and still be unidirectional. An alternating current (A.C.) is one which rises from a zero of electromotive force to maximum, falls away again to zero and then is followed by a reverse flow showing the same characteristics. If such a current takes all its variable values once over in a fraction of a second—say $\frac{1}{60}$ of a second—and repeats the operation 60 times a second—it is designated as a 60-cycle alternating current. The frequency or periodicity means the number of cycles per second. There may be two alternations in each cycle so that a 60-cycle current should give 120 alternations per second (Fig. 3).

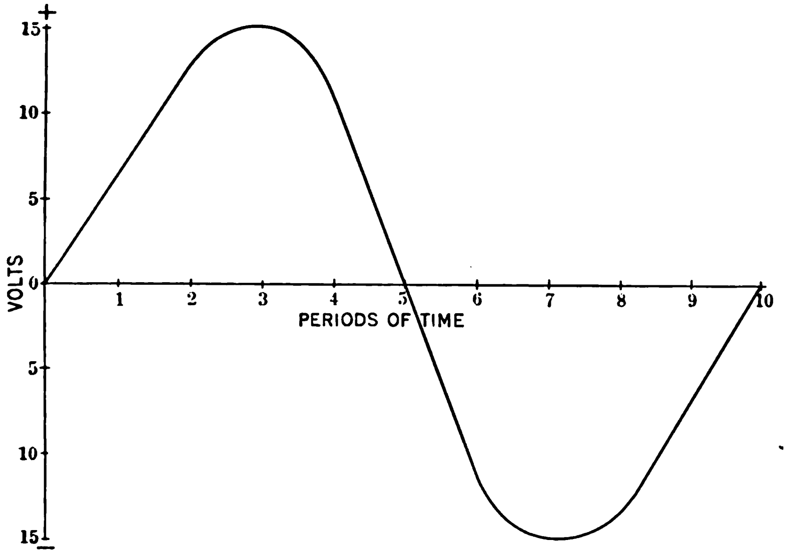

Fig. 3.—Current-time curve of a simple alternating current circuit.

When contemplating the purchase of *x*-ray apparatus one should be able to supply information relative to the type of available current supply. The manufacturer must know whether the supply is direct

or alternating. If the latter, the periodicity must be ascertained. With either current one must know the voltage.

Costly mistakes are likely to be made in wiring the laboratory or office unless the physician first selects his apparatus and decides upon the scope of his work. It is advantageous to have a current supply with a capacity of at least 30 ampères and if one contemplates doing deep therapy the line should be heavy enough to carry 60 to 100 ampères, preferably the latter. If one draws 60 ampères from a main that was designed to carry not more than 30 ampères a fuse is likely to burn out, the meter may be injured and in any event there will be a very undesirable drop in voltage, especially on a 110-volt line. It is well to see that the line ends in a heavy switch which, with the main fuses, are enclosed in a suitable wall box. Extra fuse cartridges or fuse wire should be kept on hand.

It is preferable, if possible, to use a main line that is independent of the rest of the building, unless the wiring of the building is such that there will be no fluctuation in voltage due to elevator service, etc.

In the past, when static machines and coils were employed as generators, a direct current supply was preferable, but with present-day apparatus and probably with apparatus of the future, alternating current is more desirable.

In instances where there is no power-house in the neighborhood it is possible to employ powerful storage batteries which can be charged by a small dynamo driven by a gas engine, or a static machine may be driven by a small gas engine.

The electric current from the power-house usually has a voltage of 110 or 220; the voltage necessary to actuate an *x*-ray tube is high—at least several thousand volts. An apparatus that will supply a suitable current for *x*-ray work is known as a high-potential generator. Of these there are three types: static or influence machine, induction coil, and step-up transformer. The static machine is obsolete and the induction coil is used very little in modern roentgen therapy. The static machine will be omitted entirely from the discussion. The induction coil will be described partly because it is still in use in some sections of the country but mainly because a knowledge of the physics of an induction coil will enable one to understand more readily the physics of a transformer and to appreciate its advantages.

Induction Coil.—An induction coil consists of two units—the primary and secondary. The primary unit is composed of a core and the primary winding (Fig. 4).

The Core. The core consists of closely packed, varnished soft iron wires or plates, usually the latter. In a large coil of heavy capacity the core is about 2 inches in diameter and about 18 or 20 inches in length (Fig. 4).

Primary Winding. The primary winding consists of from one to three or perhaps more layers of insulated, heavy copper wire. This may constitute a continuous winding or the various layers may be so

arranged that they can be connected in series or in parallel. Again the winding may be such that the connection can be made at various points in the primary circuit. The core and primary winding is placed in a heavy tube of ebonite or micanite to insure perfect insulation between the primary and secondary units (Fig. 4).

Secondary.—The secondary consists of many thousand turns of insulated, thin copper wire. In a large coil the secondary is usually wound in sections, each section being separated by waxed or varnished paper and connected in series. The entire secondary unit is then embedded in hot paraffin, great care being taken to exclude air-bubbles. Finally it is slid over the insulating tube enclosing the primary unit and the coil is complete. The terminals of the secondary winding terminate at the parallel or alternative spark gap (Fig. 4).

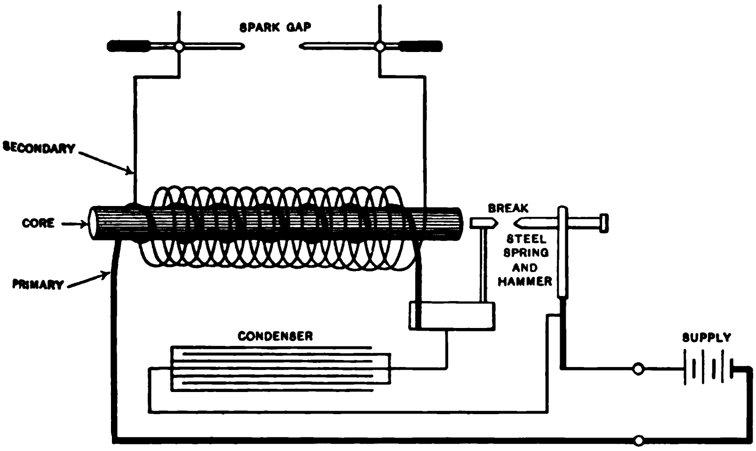

FIG. 4.—Schematic representation of induction coil (open magnetic circuit) with hammer break interrupter.

Parallel Spark Gap.—All high-potential generators are supplied with a spark gap which provides an alternative path for the current. It acts as a safety device because, in case the resistance in the secondary circuit is too high, the current will jump or arc across the air space instead of puncturing the insulation of the secondary winding. The maximum length of the spark gap is always fixed by the manufacturer. Parallel spark gaps are usually sharply pointed, calibrated and adjustable. Imagine a "soft" tube in action; the spark gap is wide open. Now, if it is slowly closed a point will be reached where sparks begin to jump across. The distance is usually recorded in inches or centimeters and indicates the voltage or potential in the secondary circuit (Fig. 4).

Theory of an Induction Coil.—When the current enters the primary winding the core becomes magnetized and a magnetic field is created. The occurrence, cessation or any variation in the intensity of this

magnetic field induces currents of short duration and high voltage in the secondary. The intensity of the induced current depends on the intensity of the magnetic field and the suddenness of its creation or disappearance. It is obvious, therefore, that some means must be provided for making and breaking the primary circuit. This is accomplished by means of interrupters of which there are several types.

Hammer Break.—This constitutes the simplest type of interrupter (Fig. 4). The hammer, which is constructed of soft iron and mounted on a thin band of steel (which acts as a spring) is attracted to the core when the latter is magnetized and, consequently, the current is broken and the magnetic field disappears. This in turn releases the hammer which then swings back and becomes part of the primary circuit. In this manner the hammer vibrates rapidly back and forth breaking and making the circuit with each vibration. The contact points are adjustable and faced with platinum. The frequency of a hammer break never exceeds 200 per second and it may be as low as 20 or 30. Very excellent interrupters of this type are now obtainable but coils so equipped are capable of only a light output.

Condenser.—*Inverse Current.*—Unless an alternative path for the primary circuit is provided there will be an arcing between the contact points of the hammer break and the mercury jet interrupters. This arcing will prevent the action of and may destroy the interrupter. The condenser supplies the necessary alternative path (Fig. 4).

We have already seen that a current appears in the secondary, both at make and break and that the intensity of the induced current depends partly upon the suddenness of the magnetization and demagnetization. The induced currents of the make and break are of opposite polarity; the former is known as the inverse current and is a source of great trouble, although recent improvements in construction have lessened the difficulty considerably. Cores can be demagnetized more suddenly than they can be magnetized so that it is desirable to have a method that will slowly build up an intense magnetic field in the primary and then very suddenly break it. In this way there is created a strong induced current with the break and very little inverse current with the make. The condenser, composed of alternate layers of tinfoil and paraffined paper or mica, receives and stores the first rush of the current and allows the core to become gradually magnetized. At break, on the other hand, the condenser is discharged very suddenly with a consequent sudden demagnetization of the core.

Electrolytic Interrupters.—When interruptions are exceedingly rapid and equally sudden it is not necessary to employ a condenser. An electrolytic interrupter not only produces interruptions of this character but it functions as a condenser. In this connection it can be stated that hammer breaks and mercury-jet interrupters are quite independent of the induction (Ruhmkorff) coil. The mercury jet and the hammer break have their own condensers and the latter possesses its own induction coil. For these reasons the modern coil contains no con-

denser and the connections on the switch board are so arranged that one can switch into the circuit any one of the various types of interrupters.

The electrolytic type of interrupter was designed by Wehnelt in 1899 (Fig. 5). The simplest type of Wehnelt interrupter consists of a glass or porcelain jar (*J*) containing dilute sulphuric acid (*a*) of about one part of acid to five of water, and covered with a porcelain or glass lid (*N*). The jar contains two electrodes; the negative or cathode is a large lead plate (*c*) which is connected to a binding post (*E*) mounted on the cover. The positive electrode or anode is a lead covered copper rod (*P*) on the lower end of which is attached a platinum point (*B*); the upper extremity ends in a binding post (*F*). This electrode is enclosed in a conical porcelain sleeve (*S*) at the lower end of which the platinum point protrudes. The circumference of the opening at the lower end of the porcelain tube is about that of the platinum anode. Also, the tube is provided with two vents (*H*) for the escape of liquid that finds its way into it. The anode is connected to a lever (*L*) which can be adjusted by a thumb screw (*G*), which in turn permits the platinum anode to protrude to any desired extent. In this manner the ampèrage or amount of current can be controlled.

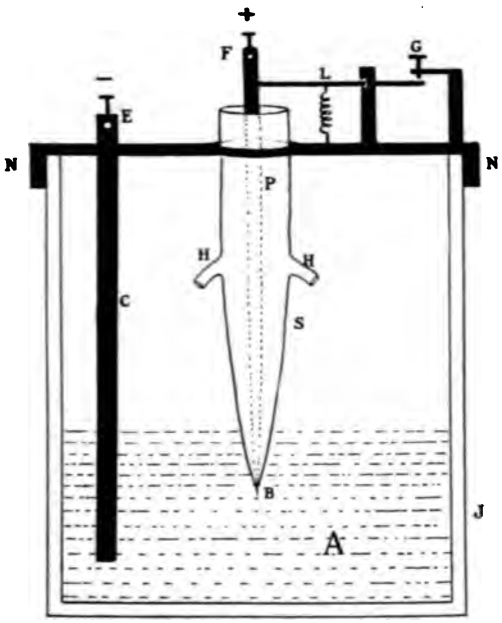

FIG. 5.—Schematic representation of an electrolytic interrupter of Wehnelt type.

The method of action of the Wehnelt interrupter is as follows: When current enters the interrupter the density of the current is so great at the small anode that the latter becomes hot and steam is formed;

electrolysis also occurs, with the liberation of hydrogen and oxygen. The bubble of gas thus formed seals the anode and prevents the further passage of electricity. Self-induction then occurs in the circuit and this induced current is discharged as a spark at the anode. The spark explodes the bubble of gas, allows the solution to come in contact with the anode and the circuit is again closed. The rate of interruption varies from 200 to 2000 per second depending upon the size of the platinum point and the depth of its emersion into the liquid conductor. The interrupter does not work well with low ampèrage (below 10 ampères) nor above 30 or 40 ampères. It works with both direct and alternating currents, but of course there is considerable loss in efficiency when used in conjunction with the alternating current.

Sources of Trouble with the Wehnelt Interrupter.—It does not act steadily with weak currents. It heats quickly and when hot it does not work well. The platinum point corrodes as also does the opening at the lower end of the porcelain tube. The result is that the bubbles do not effect complete insulation. Electrolytic interrupters are likely to permit more or less inverse current which must be choked off by the use of valve tubes.

The level of the solution must be maintained at one inch above the lower end of the porcelain tube. If it falls to within ⅛ inch from the bottom of the tube the interrupter will fail to work properly. In making the electrical connection one must be certain that the platinum point is positive. If the polarity is reversed there is danger of breaking the porcelain tube or the platinum point may fuse. Reversed polarity is detected by the fact that the induction coil will produce only short sparks in spite of a strong current in the primary and the interrupter produces a coarse, low-pitched sound. If the porcelain tube is broken, or if the platinum point is worn out or has become detached or if it extends too far into the liquid, the result is about the same as with reversed polarity.

The platinum point may be so adjusted that the interrupter and coil will work satisfactorily without any resistance in the circuit. Now if, for instance, one-half of the resistance (rheostat) is put in the circuit the interrupter will not work. The reason for this is that the platinum point is extending so far into the solution that the feeble current passing through the resistance is not strong enough to produce bubbles of steam and gas in sufficient quantities to interrupt the circuit. It is advisable, therefore, to employ the interrupter without resistance or to regulate both the platinum point and rheostat until the desired result is obtained. If the platinum point is raised until it is flush with the end of the porcelain tube a large bubble may form and remain over the opening and prevent the interrupter from operating.

Mercury Interrupters.—This type of interrupter is not subject to the ampèrage and voltage limitations that are characteristic of the electrolytic type. It causes slow magnetization and sudden demagnetization

of the core because the current is "off" longer than "on." For this reason, also, there is less inverse current. Furthermore, these comparatively long periods of rest are beneficial when very rapid interruptions are employed as the heating effect in the *x*-ray tube is less. Finally, the number of interruptions per second can be controlled by the speed of the motor, 200 a second being about the maximum.

There are a number of mercury interrupters on the market, but in principle they are all very much the same. In some the interruptions are obtained by a rapid dipping of a plunger into a pan of mercury. In others, a jet of mercury is pumped against a series of revolving conductors; or intermittent jets of mercury are forced against a single conductor. Fig. 6 illustrates diagrammatically the principle of the mercury break.

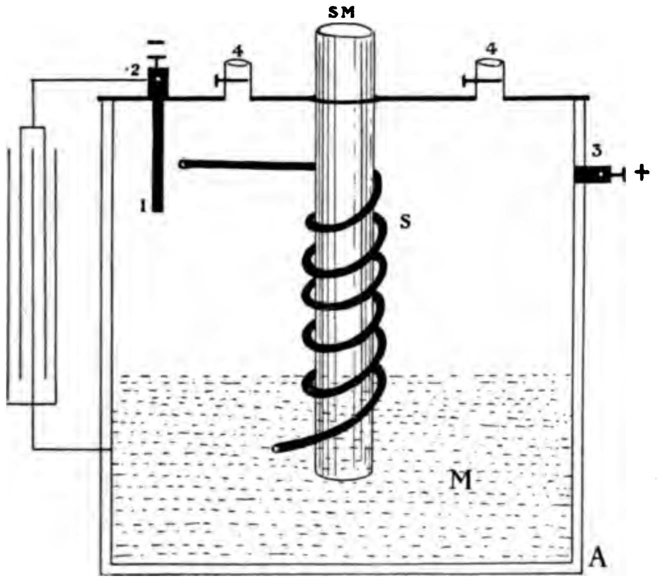

FIG. 6.—Schematic drawing of a mercury-jet interrupter.

The interrupter consists of a small iron cup (*A*) which has a gas-tight cover through which pass two inlet valves (*4*). Mounted on the under surface of the cover is an iron plate (*1*) which acts as a conductor (sometimes there are several such conductors). This plate is connected with the binding post (*2*) but carefully insulated from the cover of the cup through which it passes. Passing through the center of the cover is a revolving shaft (*S M*) coiled around and fastened to which is an iron tube (*S*). The outer end of the shaft is connected to an electric motor. The cup is partially filled with mercury (*M*). The coiled tube is open at both ends. As the shaft is made to revolve by the motor, the lower end of the tube collects mercury which is ejected from the upper end and as this upper end passes the electrode (*1*) the

stream of mercury closes the circuit. Then, as the end of the coiled tube leaves the electrode the circuit is broken. The number of interruptions per second is varied by the speed of the motor and by the number of conductors.

As the circuit is broken there is a flash or arc between the end of the revolving iron tube and the metal electrode. This arcing seriously interferes with the proper action of the interrupter and coil. The arcing can be reduced by the aid of a condenser (*C*) which is placed between the binding posts (*2* and *3*). It can be still further reduced by filling the space between the mercury and the top of the cup with a dialetric. For this purpose kerosene, lubricating oil, hydrogen and illuminating gas have been employed. Coal gas seems to produce a stronger and more abrupt quenching of the spark so that it is generally used for this purpose.

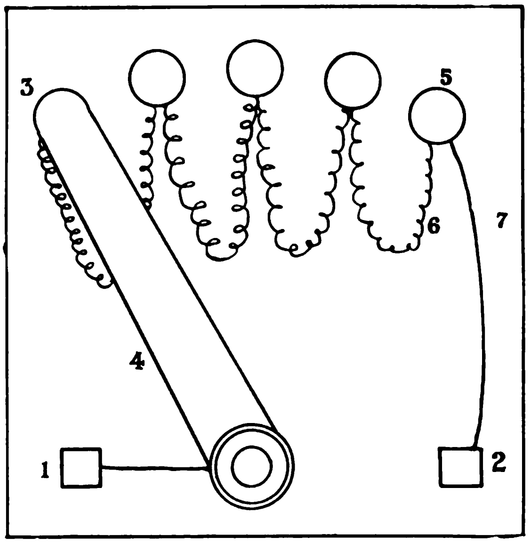

FIG. 7.—Schematic representation of a rheostat.

The possible sources of trouble with the mercury break are: the gas may become exhausted; if oil is used the mercury may become oxidized and it is then no longer a good conductor; the condenser may break down, the motor may need oiling or the brushes and commutator require cleaning.

Accompanying a coil outfit are a number of instruments some of which are indispensable. The essential accessories are herewith briefly described.

Rheostat.—A rheostat, by offering resistance to the passage of the current, allows the amount of the latter to be controlled. Rheostats are constructed in many ways, but the popular type in this country is composed of German silver wire (which offers considerable resistance)

wound on a series of asbestos tubes. The construction is such that if one section should burn out it may be replaced. The wire gets very hot during the passage of a current so that the series of tubes is placed in an iron case which is constructed so that there is a free circulation of air. The contact buttons on the iron case should be renewable without the necessity of disconnecting any of the wires. Fig. 7 illustrates the principle of a rheostat.

Referring to Fig. 7 (*7*) is the iron case enclosing the series of asbestos tubes around which is coiled the German-silver wire (*6*). The tubes are connected in series with the contact buttons (*3* to *5*). The lever (*4*) swings across the contact buttons and brings any desired number of tubes into the circuit. The binding posts for the supply are shown at *1* and *2*.

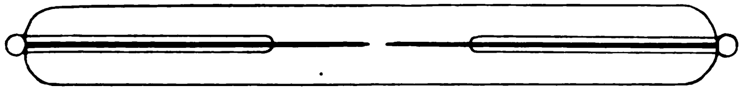

Fig. 8.—Drawing of an oscilloscope.

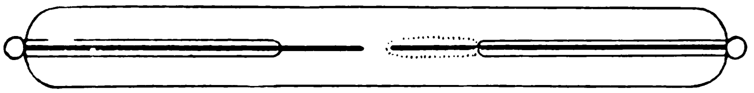

Fig. 9.—Showing absence of inverse current.

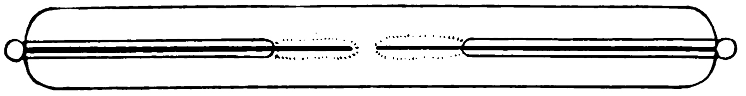

Fig. 10.—Showing inverse current.

Oscilloscope.—This instrument is for the purpose of detecting inverse current. It consists of a low vacuum tube about 5 inches in length and 1 inch in diameter. It contains two iron electrodes the inner ends of which are separated by a space of about $\frac{1}{16}$ inch. When a unidirectional high-tension current passes through this tube there is a violet glow around the end of one electrode. When there is inverse current there is a violet glow around the ends of both terminals (Figs. 8, 9 and 10).

Rectifiers and Valve Tubes.—The inverse current must be suppressed because it exerts a very detrimental affect on the x-ray tube and seriously interferes with its proper action. There are two common methods of rectifying the current from an induction coil, namely, the spark gap and the valve tube. Rectifying spark gaps may be single or multiple and are more efficient if the spark is allowed to jump from a pointed anode to a plane or cup-shaped cathode (Fig. 11). Valve tubes are considered to be better rectifiers than are spark gaps; they were first advocated by Villard. The theory of their action is

that the easiest path for a discharge through a vacuum tube is that which makes the less restricted electrode the cathode. For this reason valve tubes possess a large negative and a small positive electrode.

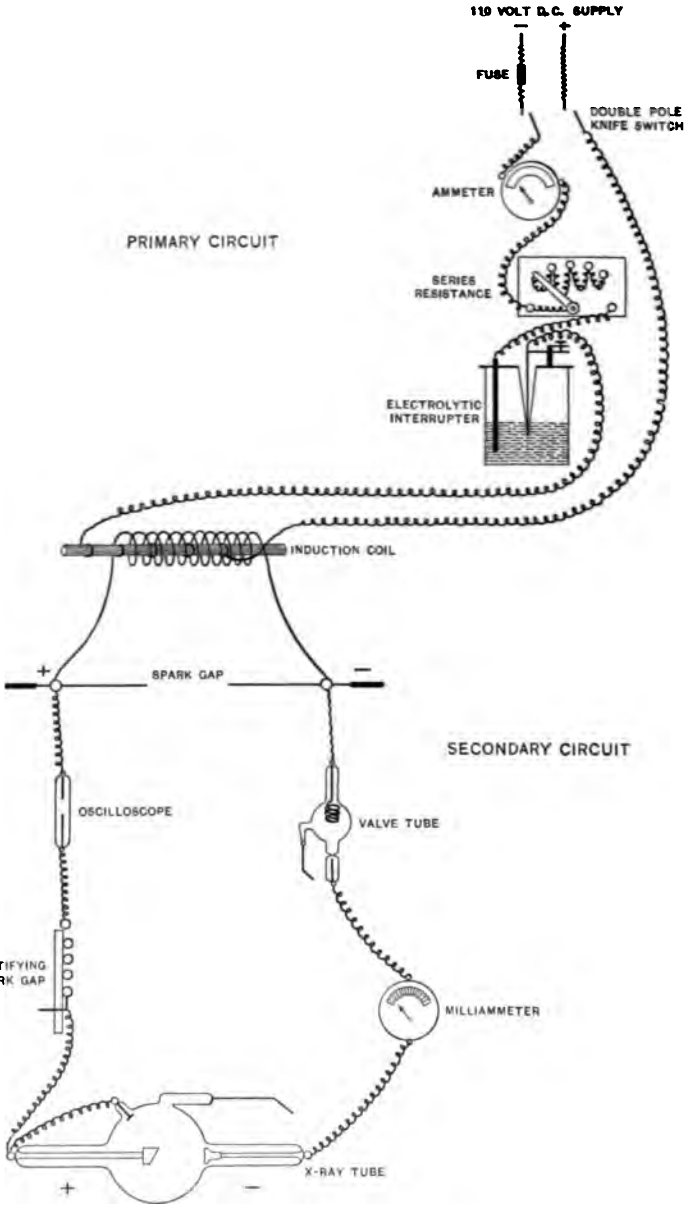

FIG. 11.—Schematic drawing, illustrating the primary and secondary circuits of an induction coil *x*-ray outfit.

The tubes are of various designs but the principle is always the same (Fig. 11). The vacuum must be low as there is a tendency for the tube to become "hardened" with use; all valve tubes have some method of reducing the vacuum. In the accompanying illustration an automatic "regulator" is shown (see p. 84). Several of these valve tubes may be placed in the circuit.

Controlling Apparatus.—A switch board consisting of a marble slab upon which are mounted the necessary switches, the rheostat, pilot lamp, fuses, ammeter, etc., is supplied with the coil. Some of these switch boards are very elaborate and contain all sorts of controlling devices. The essentials are a heavy switch for the supply, a resistance coil, fuses, and an ammeter to measure the amount of current supplied to the primary of the coil. Voltmeters, for measuring the energy input, are occasionally used and when they are it is necessary to make a shunt connection with the line. A description of the milliammeter, an instrument which measures the current in the secondary circuit, will be found on page 106. Fig. 11 is a schematic drawing to illustrate the general circuit for a coil outfit.

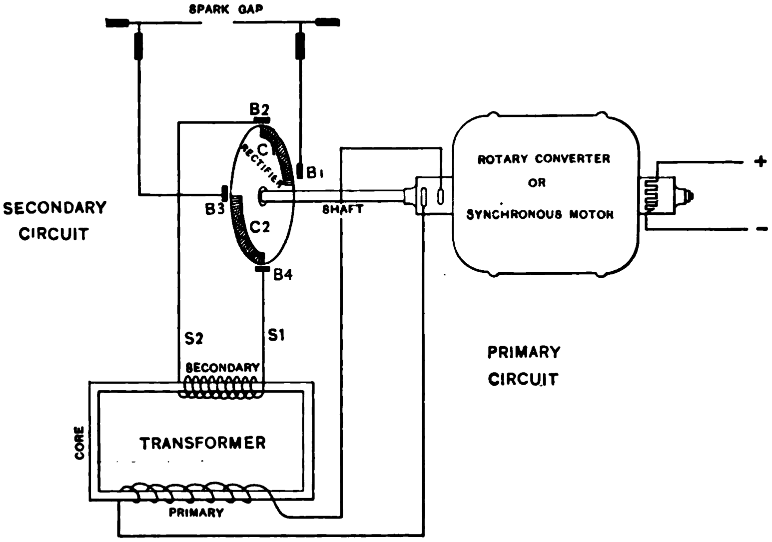

FIG. 12.—Schematic representation of interrupterless transformer (closed magnetic circuit).

Interrupterless Transformer.—There are a variety of high-tension transformers on the market. In this country the so-called interrupterless transformer is the one in general use. The interrupterless transformer was designed by H. C. Snook, of Philadelphia, in 1908; since then it has been modified and improved. (Priority is claimed by Koch, 1904.) The apparatus made and advocated by the various manufacturers differ in structural detail but the principle is very much

the same in all. The interrupterless transformer has many advantages over the coil. There is no interrupter, the current is unidirectional, the capacity is very high and the output is under almost perfect control. The current is pulsating but the pulses are absolutely regular in periodicity, a fact of technical importance in roentgen therapy.

The apparatus (Figs. 12 and 13), consists essentially of three parts —motor-converter, high-tension transformer and high-tension rectifier or commutator.

The motor-converter or rotary is only used in case the supply consists of a direct current. In this case the current is converted into an alternating current. If the supply consists of an alternating current a synchronous motor is used instead of the motor-converter.

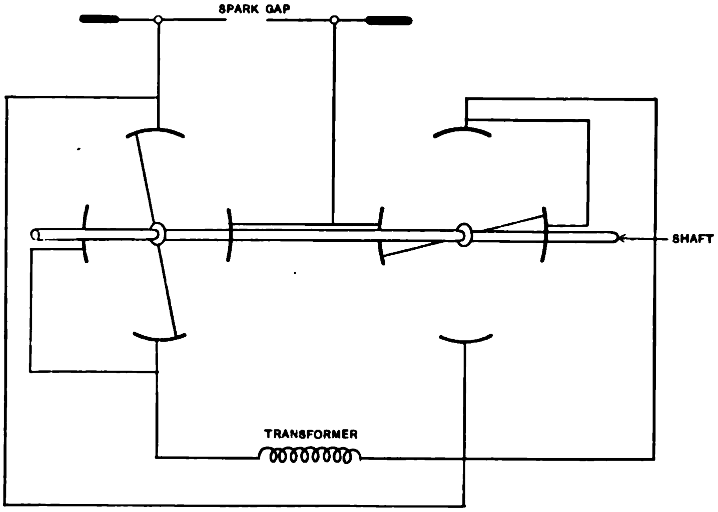

Fig. 13.—Diagrammatic representation of a high-tension rectifying switch.

The alternating current enters the transformer where it is converted by electromagnetic induction into an alternating high-tension current. The transformer is simply an oil-immersed step-up transformer. It is, in other words, an induction coil with a closed magnetic circuit. It consists of a soft iron core made in the form of a hollow square. Around one arm of the core is wound the heavy wire primary while around the opposite arm is wound the fine wire secondary. The windings of the primary and secondary and the insulation are similar to those found in an ordinary induction coil of high capacity. A series rheostat is placed in the primary circuit for the purpose of controlling the primary current.

The high-potential current from the secondary of the transformer is conducted to the high-tension rectifier where it is converted into a unidirectional pulsating current suitable for the excitation of the *x*-ray tube. The rectifier may be a disc of non-conducting material

mounted on the shaft of the motor. It has a diameter of about 18 inches and rotates with the motor, making about 1800 revolutions per minute. Referring to Fig. 12, *C*1 and *C*2 are metal conductors about 2 inches longer than ¼ the diameter of the disc. *B*1, 2, 3 and 4 are brushes or collectors placed so as to make contact with the conductors *C*1 and *C*2. When the rectifier is properly adjusted in relation to the phase of the current the apparatus works in the following manner: The high-tension terminals of the transformer are connected to brushes *B*2 and *B*4; the brushes *B*1 and *B*3 are connected to the parallel spark gap. Assuming that at a given instant the secondary terminal *S*, is positive, the high-tension current is carried to *B*4, through the conductor *C*2 and *B*3 then up to one terminal of the spark gap. The current jumps this gap or passes through the *x*-ray tube and reaches *B*1, then through conductor *C*1 to *B*2 and finally reaches the other terminal of the transformer, *S*2. Now assume that the disc makes a quarter turn. The polarity at *S* has now changed to negative. The position of the conductors on the disc have changed so that now *B*4 is in contact with *C*1. The current then travels up to the right hand parallel spark gap terminals by way of *B*1 and this terminal is negative just as it was in the first instance. The left hand high tension terminal *S*2 is positive and current is carried to *B*2; the conductor *C*2 is now in a position to carry the current from *B*2 to *B*3 and thence to the terminal of the spark gap that was at first positive and which is still positive. Thus we see that the rectifier mechanically commutates or changes the alternating high-tension current from the transformer into a direct, pulsating, high-tension current. This change takes place four times per revolution of the motor.

Another type of rectifying switch is composed of a series of conductors placed in ebonite insulating tubes. The conductors are mounted on and rotate with the shaft of the motor. As will be seen by Fig. 13 the theory is exactly the same as that illustrated in Fig. 12.

Interrupterless transformers are usually made in two sizes—2 and 10 kilowatt. A 2 K.W. transformer gives a 7-inch spark gap and is suitable for superficial therapy. It may be used also for deep therapy. Where greater penetration and heavy currents are necessary, as in deep therapy and diagnostic work, a 10 K.W. transformer is preferable.

Sources of Trouble with the Interrupterless.—The blowing out of a fuse is likely to prove very troublesome and rather confusing. If the apparatus is running on the direct current the motor-converter will cease to operate when the fuse gives out. With the alternating current there are two separate circuits, one for the synchronous motor and one for the primary of the high-tension transformer. In this case it is possible for a fuse in the motor circuit to burn out, but this would not prevent the current passing to the transformer. On the other hand the fuse in the primary circuit of the high-tension transformer might give out, but this would not prevent the motor from running. It would

be indicated by the fact that the motor ran although no current could be obtained from the spark gap. The same phenomenon would occur if the high-tension transformer broke down. In order to definitely determine whether or not the transformer has broken down, disconnect the transformer from the rectifier and then extend a piece of wire from one terminal of the high-tension transformer to within about 3 inches of the other terminal. If a spark does not jump across this space when the current is turned on the trouble is in the transformer, providing the fuse in the primary circuit has not broken.

It is, of course, absolutely necessary that the rectifier be properly adjusted to the phase of the current—it must keep step. Being mounted on the shaft of the synchronous motor or the rotary converter, the only way the rectifier can get out of step is by slipping on the shaft. It would then cease to rectify the current and the fault would be indicated by considerable sparking at various places and very little current at the parallel spark gap.

Another occasional source of trouble is that for some reason or other the synchronous motor may not synchronize. In other words it is out of step with the initial alternating supply. Such trouble is indicated by intermittent current at the spark gap.

Lack of oil will interfere with the proper running of the motor, as also, will oil that may collect in the brushes and commutator. The motor and, for that matter, the entire apparatus should be kept clean; all carbon deposits especially should be removed as they cause short circuits. Transformers are usually embedded in a case of oil. One should observe the oil level occasionally and see that it is not too low. If oil is added use only the grade that is supplied by the manufacturer.

Autotransformer (Fig. 14).—In order to control the amount of current supplied to the transformer a rheostat is usually placed in the primary circuit. The objection to a rheostat is that control of current by resistance is associated with loss of voltage and this loss of voltage is proportionately greater with heavy than with light currents. Shearer illustrates this drop in voltage as follows: "If we have a resistance of 1.5 ohms and 10 ampères current the voltage consumed will be 1.5 × 10 = 15 volts. If we have the same resistance and 60 ampères, 1.5 × 60 = 90 volts will be used up in the control; and if the line voltage is 220, only 130 volts can be useful on the *x*-ray transformer primary." It may help the reader to understand this drop in voltage if he will visualize a transformer in action. Imagine a Coolidge tube being actuated by an interrupterless transformer. Let us assume that the rheostat control is set on the sixth button, that the milliammeter registers 2 and the spark gap 7. Now a little more current (from the storage battery) is allowed to pass through the Coolidge filament—the filament becomes hotter, the potential is lowered and more current passes through the tube as shown by the milliammeter. That this current is of lower voltage is shown by a shorter spark gap.

The autotransformer controls the current in the primary circuit

by the impedence of autoinduction and there is considerably less drop in voltage when the current is increased than when a rheostat is employed. This impedence may be briefly explained in the following manner: When an alternating current is passed through a wire wound around an iron core an induced electromotive force of opposite sign is created when the current is made. This counter electromotive force retards or impedes the primary current. The degree of impedence depends upon the strength of the counter electromotive force and

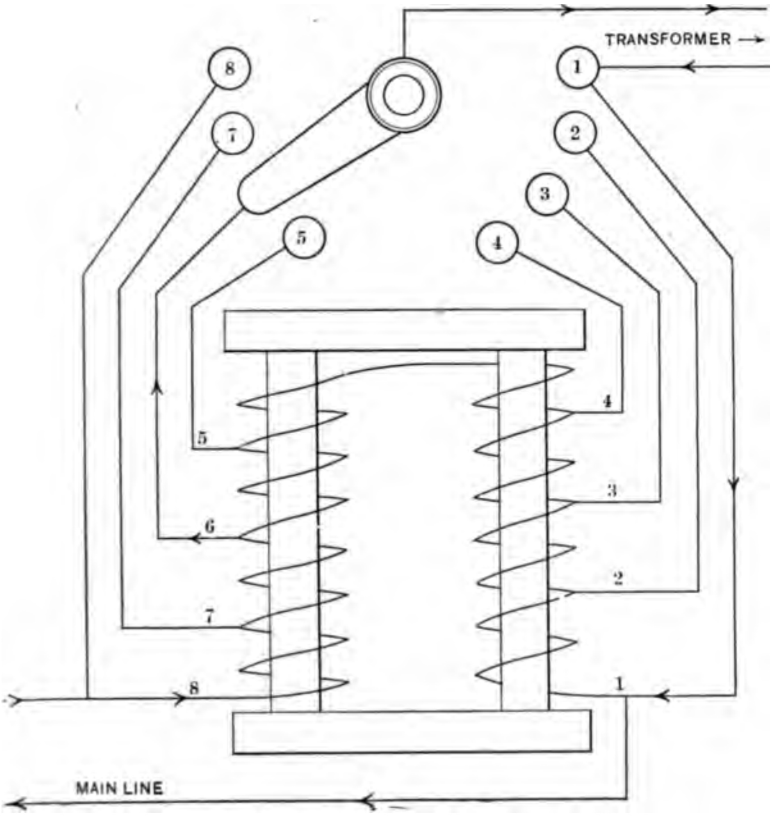

Fig. 14.—Schematic drawing of an autotransformer. (Shearer.)

this in turn is in relation with the number of turns of wire included in the circuit. With any given setting on the autotransformer (number of turns of wire in the circuit) the amount of current may be increased or diminished with relatively little change in voltage. Shearer shows the behavior of the rheostat and autotransformer on a particular machine by means of a chart that is herewith reproduced (Chart 10). "Starting at 10 M.A. and 60 K.V., and raising the tube current on a fixed rheostat setting, gives the series of currents and voltage shown by

the line *A.C.;* while on a fixed autotransformer setting we have the line *AB*. Since the quantity of radiation (measured photographically) increases as the current and the square of the voltage, we may compute the relative amount of radiation regardless of penetration. Curve *DE* shows the rheostat delivery down as low as useful rays are produced; *DF* shows the delivery on the autotransformer up to 60 M.A."

As pointed out by Shearer the autotransformer is of special value when the filament current is not steady. "Thus, if the tube current is changed from 10 to 15 M.A., with a rheostat control the radiation would be reduced in quantity from 32 to 25 arbitrary units and also would be much less penetrating; while with the autotransformer the same change would result in an increase in quantity from 32 to 50 units very slightly less penetrating than at 10 M.A."

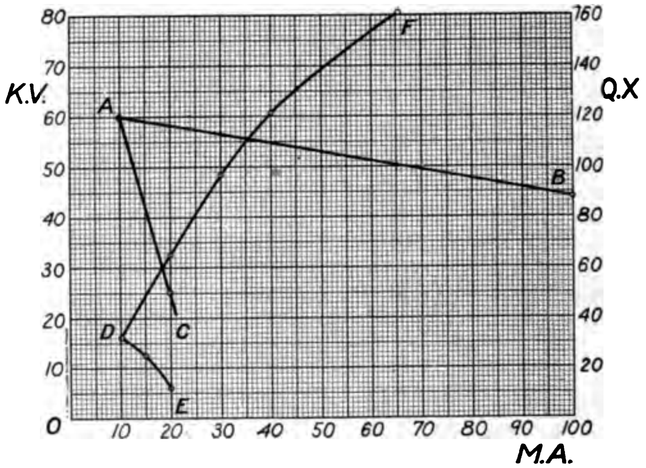

CHART 10.—Relation of *x*-ray production on two types of control. On rheostat control we have A C as the voltage-current lines. Voltage ordinates at the left. D E, corresponding X-radiation quantity, ordinates at the right. A B, autotransformer chart line. D F, corresponding quantity line. Quantity in arbitrary units. (Shearer.)

Portable Transformers (Figs. 15, 16 and 17).—There are a number of portable transformers on the market. They have been given various names—portable transformer, bedside unit, dental *x*-ray unit, etc. All, however, are based on the same principle. The apparatus consists of a combined cabinet and tube stand. The tube stand is of wood and is mounted on the top of the cabinet. The cabinet is mounted on four rollers. The tube (a description of which will be found in Chapter IV) is of the radiator (self-cooling and self-rectifying) Coolidge type. This is covered with a heavy lead glass shield containing an opening for the passage of the *x*-rays. The cabinet contains the D.C. rotary converter, a transformer and a control for the Coolidge filament current. The handle for this control is situated on the top of the cabinet. A specially constructed milliammeter is mounted on the top

of the cabinet. There is no spark gap, voltmeter or rheostat, the apparatus operating on a fixed resistance. The apparatus was designed for use with the ordinary interior wiring for lighting purposes. Therefore its power limit was fixed to correspond with the usual fuse capacity of such supply lines. It was not designed to permit variation by the operator of either current or voltage. It is possible to obtain a bedside unit equipped with accessories that will permit operation with practically any supply system. Such units possess a rotary converter for a 110 volt direct current. As there is no rotating rectifier there is no need of a synchronous motor. Therefore, the apparatus will operate on an alternating current of any ordinary frequency. For use with a 220-volt D.C. current it is necessary to have a 220-volt rotary. For a 220-volt alternating current a specially constructed autotrans-

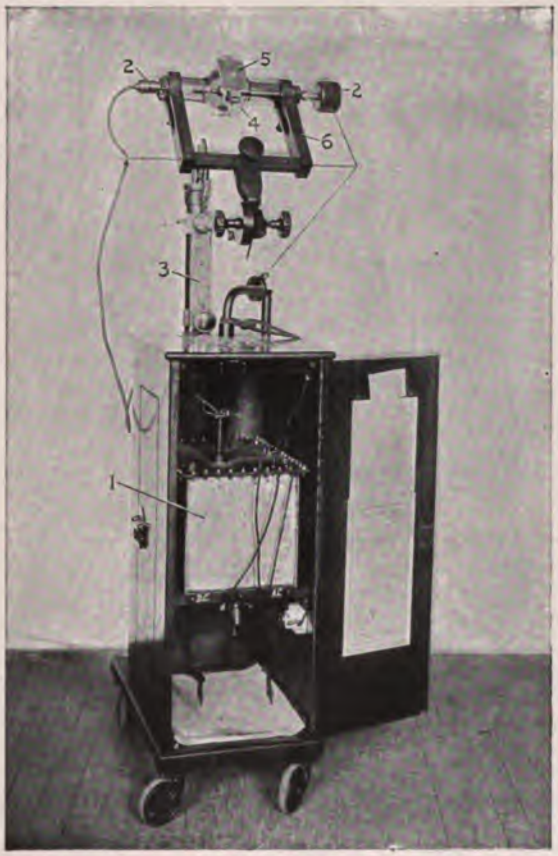

FIG. 15.—United States Army bedside unit, complete for alternating-current operation; double throw switch to be drawn to the right, loose connections below for rotary converter in using direct current. (Shearer.)

former is placed in the circuit. For office use or for portable purposes in a restricted territory it is usually possible to get along with a 110-volt D.C. rotary or a 110-volt alternating current without a motor. It is important, however, to ascertain if a 220-volt current is likely to be used and if so, to have the necessary accessories supplied with the apparatus.

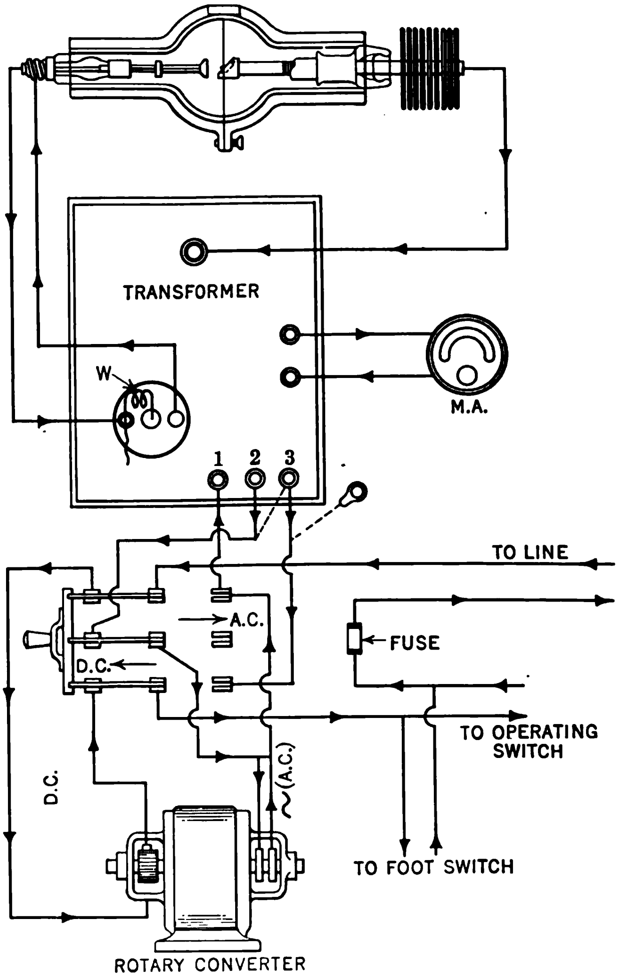

Fig. 16.—Wiring diagram for connections, United States Army bedside unit for 110–220 volt, d. c. or 110 volt. a. c. (Shearer.)

It will be noted that there is no rectifier in the apparatus. The high-tension, alternating current from the transformer is conducted to the tube without rectification. As will be seen in the next chapter current can pass in one direction only through this particular type of *x*-ray tube; therefore, the tube acts as a rectifier.

The primary circuit supplies power for both the filament lighting and *x*-ray operation so that only one switch is necessary. When this switch is closed current of suitable voltage passes through and heats the filament. At the same time the high potential current passes through the tube and produces the *x*-rays. The apparatus is designed to operate on 5 milliampères in the secondary or tube circuit. This milliampèrage is obtained by adjusting the filament control. With 5 milliampères the spark gap is said to be 5 inches (60,000 K.V.).

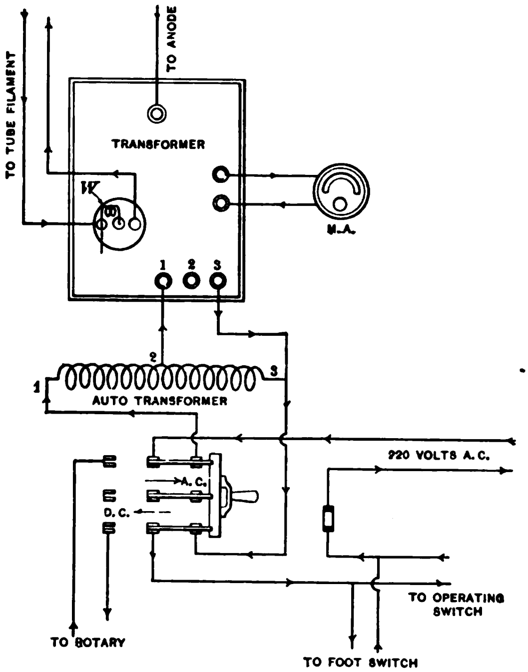

FIG. 17.—Wiring diagram for connections, United States Army Bedside Unit for 220 volts a. c. circuit.

Oil-Immersed X-Ray Generating Outfit.—Very recently Coolidge has published an account of an *x*-ray outfit in which the transformer and the Coolidge tube is contained in the same tank of oil. The complete outfit is shown in Fig. 18. The "rectangular metal box, adjustably mounted on the tube stand, contains the *x*-ray transformer and below this, in the same tank, the special *x*-ray tube. A low-tension cable is seen leading from this generating outfit to the control box at the right of the picture. A second cable, attached to the other end of the control box, leads to the supply mains.

"A side view of the generating outfit in partial cross-section is shown in Fig. 19. In this case the cone has been removed and the outfit has been rotated through an angle of 180 degrees from the position shown

FIG. 18.—Oil-immersed x-ray generating outfit complete. (Coolidge.)

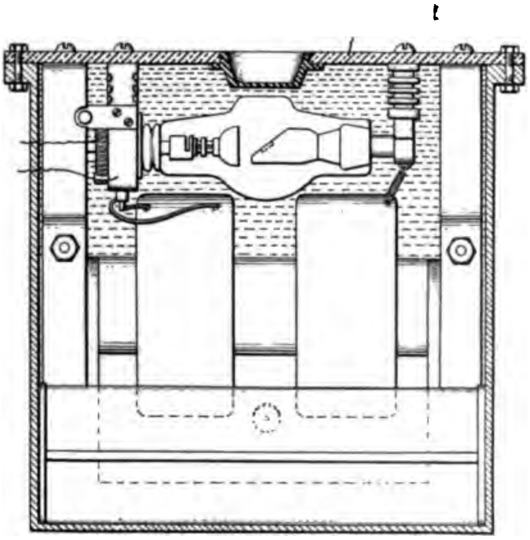

FIG. 19.—Schematic drawing of oil-immersed x-ray generating outfit. (Cooli

in Fig. 18, so that the x-ray tube is now above instead of below the transformer."

The x-ray tube is of the Coolidge type but it is very small and with the exception of a lime glass window opposite the target, it is composed of heavy lead glass. The x-rays pass through the lime glass window, then through a thin layer of oil and finally through a thin reëntrant window in the bakelite cover of the tank. The radiation is therefore filtered by these materials.

The apparatus is so constructed (oil-expansion chambers) that it may be operated in any position. A layer of aluminium is placed in contact with the bakelite cover and metallically connected to the metal tank. "If then the tank is connected to earth, the whole high tension system is inside of an earthed metal enclosure from which nothing but x-rays can emerge. The high-tension danger is then seen to be completely eliminated. The generating outfit as shown in Fig. 18 is suitable for 10 milliampères and 60,000 volts (useful) and weighs 54 pounds." The oil keeps the tube cool, therefore inverse current cannot pass. It is said that the tube may be run at 60,000 volts and 10 milliampères for ten minutes without overheating.

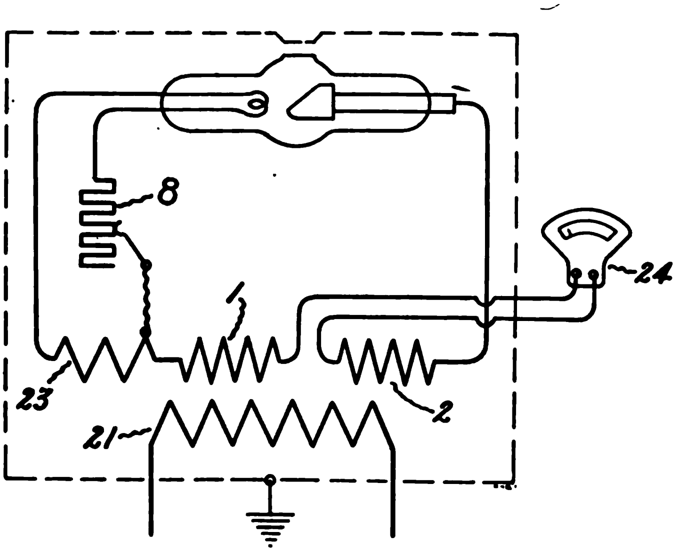

FIG. 20.—Diagram illustrating wiring and circuit of oil-immersed x-ray generating outfit (Coolidge.)

"A schematic wiring diagram is shown in Fig. 20 in which *21* is the low-tension coil of the transformer and *1* and *2* are the high-tension coils. Coil *23* consists of but a few turns of relatively coarse wire. It is electrically connected to the high-tension coil *1*, and serves as a source of heating current for the filament of the x-ray tube. The filament current is controlled by a little rheostat *8*. Wires lead from

the inner ends of the high-tension coils out through the metal tank, indicated in the figure by the dotted rectangle, to *24*, a milliammeter located in the control box. At the bottom of the figure a connection is shown running from the metal tank to ground."

The control box consists of a special autotransformer by means of which it is possible to vary the voltage supplied to the *x*-ray transformer by steps of 2 volts through a range of 32 volts. "The voltage delivered by the autotransformer to the *x*-ray transformer is indicated by a voltmeter and the corresponding high-tension voltage is known from a sphere-gap calibration made before the transformer was put in the tank."

For heavy work it is possible to use air-cooled and water-cooled targets.

Coolidge sums up the advantages of the oil immersed system as follows:

1. Elimination of all danger of electric shock to patient and operator.
2. Elimination of all corona discharges with attendant noise and odor.
3. Elimination of fire risks in the presence of ether vapor.
4. Possibility of any amount of *x*-ray protection, for, if necessary, the tank can be lined with metallic lead.
5. Practicability, even in small rooms, of the use of as high a voltage as that for which an *x*-ray tube can be developed.
6. Possibility of bringing the focal point much nearer the patient than is ordinarily practicable.
7. Makes the tube mechanically stronger by permitting the use of shorter arms and a shorter anode rod.
8. Gives greater heat conduction from focal spot to the outer end of anode rod by shortening the distance the heat has to travel.
9. Assists in removal of heat from the outer end of the anode rod, as oil is a more effective cooling medium than air.
10. Permits of the safe and convenient use of tap water for the cooling of the oil or anode.
11. Reduces the danger of tube breakage by putting the tube in a good damping medium (oil) and inside of a metal container. It furthermore eliminates all handling of the tube.
12. Eliminates effect of humidity on performance of apparatus, a matter of considerable importance in moist climates. It also prevents the deposition on the tube of a conducting layer of salt spray at the seashore.

Wiring for High-tension Circuit.—The safest and most convenient type of wiring for the high-tension circuit is the overhead or so-called aërial system. It is the rule to use plain heavy copper wire or better still, brass tubing $\frac{3}{8}$ inch in diameter. The wires or tubing should be two or three feet apart, the same distance from the ceiling and walls, and between eight and ten feet high. The ends of the wires are attached to the wall by means of adjustable insulating rods. If they must pass

near a conductor, such as a pipe, or chandelier both wires and the pipe should be thoroughly insulated at this point. The overhead system may be employed for both the gas and the Coolidge tube. In the latter instance two of the wires conduct the low voltage filament current. The wires or tubing must be kept clean and there must be perfect contact at all connections. The light, flexible copper wire for the purpose of connecting the overhead system with the *x*-ray tube, is usually wound on a reel (Fig. 21) and this reel can be moved along the overhead wires or tubing.

All the control instruments, fuses, meters, etc., are mounted on a marble slab. This switch-board may be attached to the apparatus, may be on a movable stand or mounted in a protection booth or even in another room. The operator is at the switch-board during the entire exposure which necessitates placing the latter in a booth or behind a screen that is suitably protected from the *x*-rays. Figs. 22 and 23 illustrate floor plans that may be of help to the beginner. In Fig. 22 the arrangement is very simple and will do for light work, such as is required in dermatology. For heavier work it is advisable to provide for better protection.

FIG. 21.—Double reel for Coolidge tube used with overhead high-tension wiring.

The selection of a table and tube stand will depend upon the requirements of the individual operator. For superficial therapy a complicated stand is not necessary. It is difficult to obtain a stand that will answer perfectly the many requirements of a busy *x*-ray laboratory even when only superficial work is to be done. The principle requisites for the stand are:

1. Stability without being cumbersome.
2. That will permit the usual working distance of 8 inches without having metal parts close to the skin.
3. That can be quickly, easily and accurately adjusted to the part to be treated.
4. That will permit confinement of radiation to a very small area or that will allow a spread of radiation over a large area at will.

A good stand for superficial requirements is represented by the type shown in Fig. 25. This consists of a vertical metal rod mounted on a base composed of three legs on rollers. A metal horizontal arm is fitted on the vertical rod. This can be moved up or down or rotated or securely locked in position: Inasmuch as the horizontal arm is not counterbalanced, there is a safety device which consists of a metal clamp which can be securely locked at any position on the vertical rod. This will prevent the horizontal arm from sliding down through care-

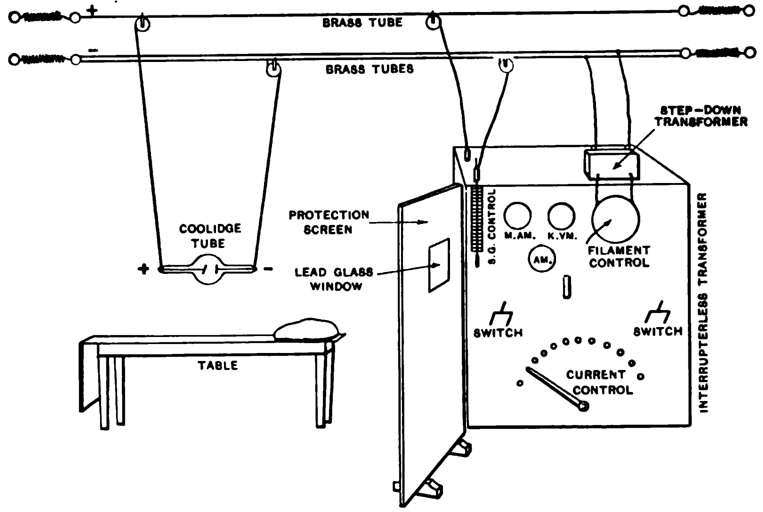

FIG. 22.—Drawing to illustrate floor plan for *x*-ray laboratory.

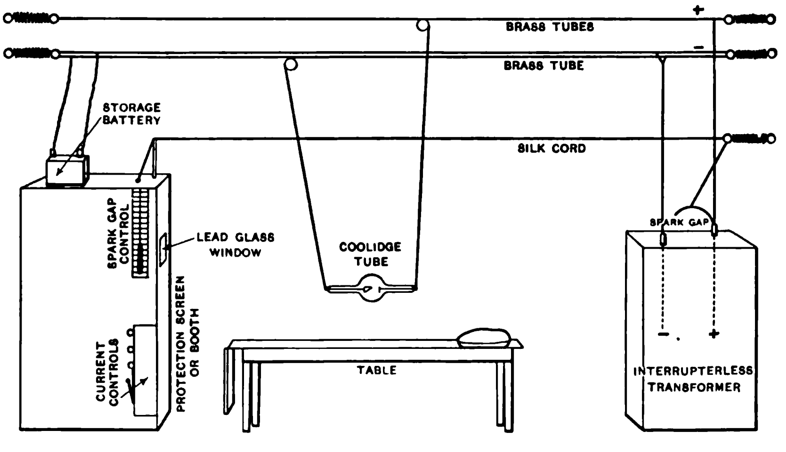

FIG. 23.—Drawing to illustrate floor plan for more elaborate outfit.

less or hurried locking. At one end of the horizontal arm is mounted by means of an adjustable joint, a lead-glass bowl for the reception of the x-ray tube. At the bottom of the bowl there is an adjustable lead diaphragm into which may be inserted aluminium or other filtering material.

FIG. 24.—Three-leaf lead lined protection screen.

The stand is strong, light, easily, quickly and accurately adjusted and securely fixed in almost any position. The wall of the tube can be brought to within a few inches of the skin without projecting metal parts coming in contact with the patient. The opening at the bottom of the lead-glass bowl will not, however, permit sufficient spread of radiation at a working distance of 8 inches to satisfactorily treat such large surfaces as are met with in dermatological practice. For this

purpose it is advisable to have a square wooden box, lined with a that is somewhat impervious to the *x*-rays, so constructed tha

FIG. 25.—Tube-stand suitable for therapeutic work.

be quickly substituted for the lead-glass bowl on the horizontal arm. The bottom of the box, being wide open, provides a wide spread of the radiation. Such a box is shown in Fig. 26.

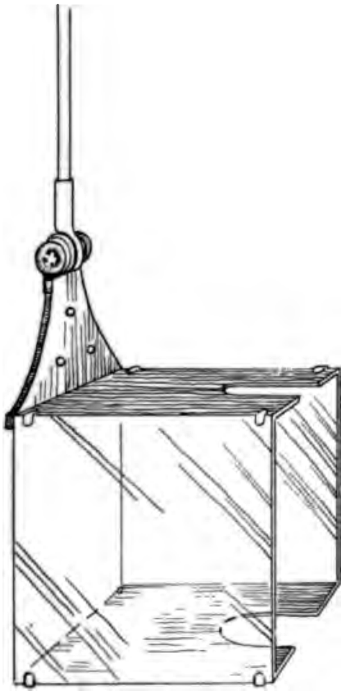

Fig. 26.—Suitably lined wooden tube-box for use with tube-stand shown in Fig. 25 for superficial therapy.

For those who desire to work with the tube very close to the skin it is advisable to have a wooden tube holder that can be used in connection with the stand shown in Fig. 25. The tube itself may be covered with pliable material that will absorb a large percentage of

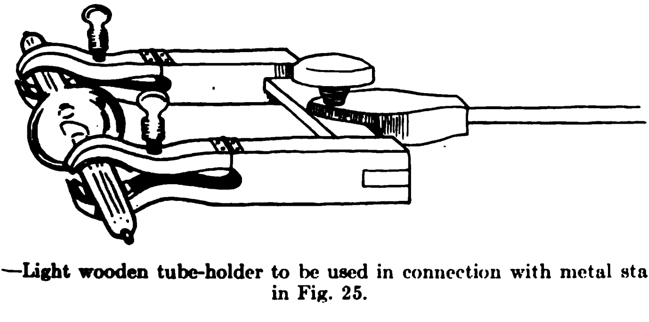

Fig. 27.—Light wooden tube-holder to be used in connection with metal stand shown in Fig. 25.

radiation used for superficial therapeutic purposes. Such an outfit is shown in Fig. 27.

A practical stand (recently developed) for superficial therapy (and which may be employed in deep therapy) is shown in Fig. 28. It

Fig. 28.—Tube-stand used by the author for superficial therapeutic work.

consists of a strong perpendicular metallic tube. This may be mounted on three legs or on a steel rail attached to the table. The horizontal arm is made of metal and it is counterbalanced. It is freely movable upward, downward or sidewise. It may be quickly and securely locked in position and the act of locking will not move the position of the

horizontal arm a fraction of an inch. This is an important point when doing rapid and accurate work.

The tube-holder consists of a wooden box lined with material that eliminates all but the most penetrating radiation. One side of the box contains a window of heavy lead glass. The mounting of the box on the horizontal arm and the latter on the vertical tube is so arranged that any desired position or angle may be had. No metal parts come near the patient even when the wall of the tube is but an inch or two from the skin.

The bottom of the box (represented by the dotted lines) swings back out of the way permitting a wide spreading of radiation. The bottom is provided with diaphragms of varying size into which a filter can be inserted.

An ordinary wooden table equipped with gynecological stirrups, a disappearing right-angle shelf (for arm treatments in the recumbent position), drop leaves at both ends and a padded leather cover will answer the purpose of a table admirably. Metal tables are objectionable.

NOTE.—Photographs of cabinets containing interrupterless transformers and photographs of many accessories used in roentgen therapy have been omitted from this book. The general appearance of the finished products vary with the make and each manufacturer improves his apparatus every few months. In order to become acquainted with the latest products the reader is advised to obtain catalogues from the various reliable manufacturers. The chief requisite is a knowledge of the physics and mechanics of *x*-ray apparatus. It is hoped that the drawings and the text will answer this purpose.

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For further details regarding *X*-ray apparatus see: Kaye, G. W. C.: *X*-rays, 1917, N. Y., Longmans Green & Co.; Knox, R.: Radiography, *X*-ray Therapeutics and Radium Therapy, 1916, N. Y., The MacMillan Co.; Swoope: Lessons in Practical Electricity, 15th ed., N. Y., 1917, D. van Nostrand Co., article by J. S. Shearer in the United States Army *X*-ray Manual (loc. cit.). Also descriptive catalogues of various manufacturers of *x*-ray apparatus and accessories.

CHAPTER IV.

X-RAY TUBES.

THERE are two general types of *x*-ray tubes—the gas tube and the electron tube. The former is a modern modification of the original Crookes' tube, while the latter (Coolidge tube) operates upon a different principle. For therapeutic purposes the gas tube is becoming obsolete but it is desirable to know something of its construction and characteristics.

GAS TUBES.

An *x*-ray tube consists of a blown glass bulb of varying size into which are inserted and sealed three electrodes. These electrodes are known as anode, cathode and anticathode (Fig. 29). In some tubes the separate anode is omitted, the anticathode in this case functions also as the positive pole. As a matter of fact the anticathode is generally called the anode. In other words the two terms have become synonymous. The ordinary tube is constructed of soda glass which allows the *x*-rays to pass. Tubes designed for superficial therapy are sometimes made of lead glass which prevents the passage of a large proportion of the *x*-rays generated. Such tubes have a soda glass window for the treatment of small areas.

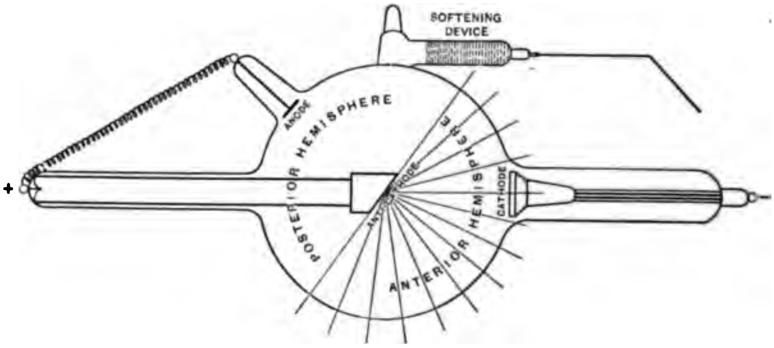

FIG. 29.—Schematic drawing of the gas type of *x*-ray tube.

The gas tube is exhausted to a very low atmospheric pressure (high vacuum) but not as completely as is possible—some gas is allowed to remain.

Anode.—A separate anode (positive pole) is of questionable importance and is frequently omitted. It is composed of aluminium and is connected externally with the anticathode.

Cathode.—The cathode (negative pole) is a concave disk of aluminium placed just within the proximal end of a glass side tube on the bulb.

Anticathode.—The anticathode or target, is mounted on an iron tube. The target is inclined at 45 degrees to the beam of cathode rays. The distance between cathode and anticathode is important and is adjusted by the manufacturer.

Kaye gives the following desiderata for an anticathode for use with heavy currents:

1. High atomic weight—as the fraction of cathode ray energy transformed into x-rays increases with increase of atomic weight.
2. High melting-point—to permit sharp focussing of the cathode rays without fusing the target.
3. High thermal conductivity—to diminish local heating.
4. The metal should not vaporize readily below its melting-point.

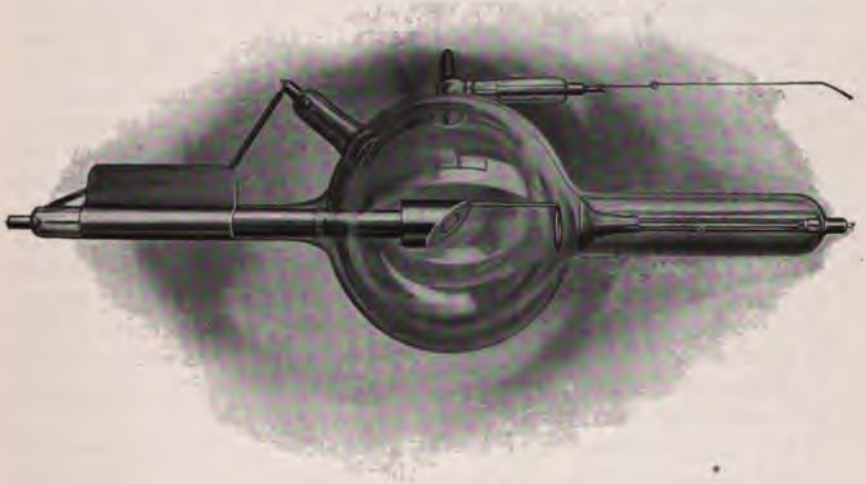

FIG. 30.—Photograph of an x-ray tube (gas type).

Inasmuch as there is no advantage in a small focal point in therapeutic work, one should select a treatment tube provided with a wide focus. However, even with a wide focus, the production of heat at the target when heavy currents are used, is enormous. In the more expensive tubes the anticathode is composed of a heavy block of copper into which is welded a button of tungsten (Fig. 30). In the cheaper tubes the copper is faced with nickel and the latter with a thin facing of platinum. Tubes fitted with air-cooled and water-cooled targets are obtainable but they have never been popular.

A gas tube fluoresces when in action and this fluorescence is practi-

cally limited to the portion of the bulb in front of the target—hence the terms anterior and posterior hemispheres (Fig. 29).

Regulation of Vacuum.—In practical work it is customary to speak of a low, medium or high vacuum. Synonyms for the first and last of these terms are "soft" and "hard." A "soft" tube is one containing a relatively large amount of gas and emits "soft" or slightly penetrating *x*-rays. A "hard" tube is one that contains less gas and which emits "hard" or very penetrating *x*-rays. The terms hard, medium and soft have been employed for years and are intended to give some idea of penetrability. All gas tubes are fitted with some device for regulating the vacuum. Inasmuch as a gas tube tends to "harden" spontaneously the usual "regulator" consists of a "softening" device. The simplest "softening" device is the "automatic regulator" attached to the tube. This consists of a glass side arm (Fig. 29) containing a substance from which gas is emitted when heated. The contained substance is usually asbestos or mica; when electricity is allowed to pass through these substances they are heated and gas, usually CO_2 and water vapor, is liberated and enters the tube. A piece of copper wire sealed in the "regulator" can be set at any desired distance from the negative terminal of the *x*-ray bulb. When the tube "hardens" the resistance increases and sparks jump from the terminal to the wire and the electricity is conducted to the "regulator." For accuracy and convenience the "regulator" is usually operated and controlled by means of a string from behind the protecting screen.

Some *x*-ray bulbs are fitted with a small, platinum or palladium tube which is open at one end. The open end is sealed in the bulb. When the metal tube is made red hot by means of a flame a little hydrogen diffuses through and the vacuum is lowered. This softening device is known as the osmosis regulator. The theory of its action is that hydrogen will pass through red hot platinum or palladium from a high to a low hydrogen pressure.

A very ingenious use of the osmosis method has been made by Snook and Kelly who developed the hydrogen tube. This tube is pumped free of gas and then a pure hydrogen atmosphere is provided by permitting a little hydrogen to enter the tube—just sufficient to provide the necessary ionization for conductivity. The bulb is fitted with two osmosis tubes one of which is exposed to the air while the other is enclosed in a small glass bulb containing hydrogen at about atmospheric pressure. The osmosis tubes are heated by sparks which jump from adjacent conductors. If the metal tube contained in the hydrogen reservoir is heated, gas enters the *x*-ray bulb; if the other one is heated, gas passes from the *x*-ray bulb into the air. In this manner the tube can be "softened" or "hardened" at will. The hydrogen tube possesses many advantages over other types of gas tubes for therapeutic work and it probably would have become more popular if it had not been for the advent of the Coolidge tube.

COOLIDGE TUBE.

In 1913 W. B. Coolidge (working in the Research Laboratory of the General Electric Company), succeeded in constructing a new and powerful *x*-ray tube with a pure electron discharge. Richardson and others had previously shown that electrons were emitted from hot metals and it was naturally suggested that the cathode stream in an *x*-ray tube might be attained by heating the cathode. Langmuir, Wehnelt and Trenkle, Lilienfeld and Rosenthal, all experimented with various forms of hot cathodes and their findings were of the utmost importance from a physical and evolutionary point of view. To Coolidge, however, must be given the credit for developing the first practical electron type of *x*-ray tube. This remarkable tube has already stood the test of time. It has revolutionized roentgen therapy and it is doing the same with roentgenography. The three things that stand above any other single events in the evolution of practical *x*-ray work are the development of the focus tube by Jackson, the interrupterless transformer by Snook and the pure electron type of tube by Coolidge.

Fig. 31.—Photograph of a Coolidge tube.

The Coolidge tube (Fig. 31) is decidedly revolutionary. It is exhausted to a few hundredths of a micron—in other words, to as low pressure as is possible. Practically speaking there is no residual gas and the supply of electrons is from the hot cathode. The tube does not fluoresce when in action. The cathode (Fig. 32, *A*) consists of a spiral filament of tungsten wire. The filament is heated by current from a small storage battery or from a step-down transformer. In the filament circuit are placed an ammeter and a rheostat or choke coil (Fig. 33). By means of the current control the filament current can be regulated by very fine steps from 3 to 5 ampères.

The focussing device consists of a cylindrical tube of molybdenum (Fig. 32, *B*) mounted so as to be concentric with the filament and metallically connected to it.

The anticathode, which also functions as anode, is a single block of tungsten mounted on a molybdenum support. The bulb is 7 inches in diameter.

As the supply of electrons depends upon the heat in the filament it is necessary to have a steady filament current. Storage batteries have a steady electromotive force and they are frequently employed for this purpose. An electromotive force of about 10 volts (maximum 12 volts) is required. After the filament has become heated the resistance of the filament circuit becomes constant and the current becomes steady.

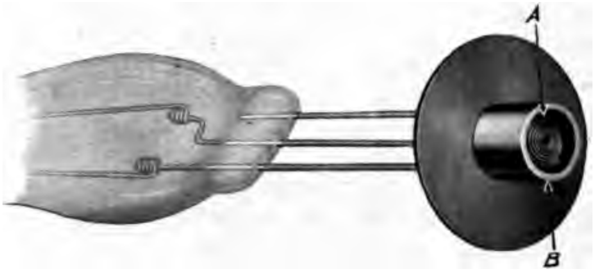

FIG. 32.—Cathode of the Coolidge tube. (a) Filament; (b) focusing cylinder.

Storage Battery.—The simplest type of storage battery, or accumulator, consists of a cell in which there are two sets of lead plates (positive and negative) immersed in an electrolyte (conducting solution—sulphuric acid, about 1 to 5). The negative plates, coated with "spongy" lead are connected together as, likewise, are the lead-peroxide-coated positive plates. Both sets of plates are separated by dielectrics. The capacity of a cell depends upon the size and number of the plates. Each cell, regardless of its capacity, gives a working voltage of 2 volts. For the Coolidge filament, in therapeutic work, it is customary to use two sets of three cells, each set being capable of supplying $2\frac{1}{2}$

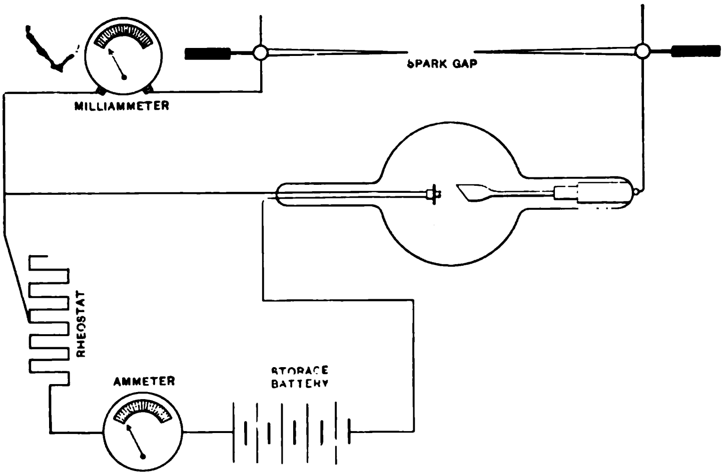

FIG. 33.—Drawing illustrating filament circuit with storage battery. (Shearer.)

ampères when connected directly to the filament. The negative plates of one set are connected to the positive plates of the second set. Such a battery will deliver a current of 5 ampères. Fig. 33 shows the storage battery filament circuit.

Storage batteries are rated in ampère hours: a 10 ampère-hour battery will deliver 10 ampères for one hour, 1 ampère for ten hours, ½ ampère for twenty hours and so on, and its charging must be in the same proportion.

Storage batteries do not store electricity. The electricity produces a chemical action which results in the storing of energy. In discharging, this chemical action is reversed and a flow of electricity results.

Shearer gives the following as the main points to be kept in mind when using storage batteries:

1. They must be charged on direct current.
2. The charging rate given by the maker should not be exceeded.
3. The discharge rate allowable should not be exceeded.
4. Loss of electrolyte by evaporation must be replaced by adding distilled water. The tops of the plates should never be allowed to show above the level of the solution. As a rule distilled water will have to be added about every two weeks. The battery should never be completely filled.
5. Loss of electrolyte by accidental spilling must be replaced by adding sulphuric acid solution of the proper density.
6. In making the acid solution never pour water into the acid, but pour acid slowly into the water.
7. Do not overcharge, nor discharge after the voltage falls below 1.8 volts per cell.
8. Do not let the battery freeze.
9. Do not let the battery stand idle for long periods. If it must be laid up, charge it fully and draw off the solution. For short periods, put a high resistance across its terminals and let it slowly discharge and charge it up again at intervals.
10. If overheated by too high current passing in or out, the active material is likely to crumble and fall to the bottom of the cell and cause a short circuit, whereby the battery discharges internally.
11. The discharge voltage falls quite rapidly after a battery is first charged, then more slowly until nearly discharged, then rapidly. When used on a Coolidge filament, which requires about 4 ampères, it is well to pass the full voltage of the battery through a suitable resistance for three or four minutes to bring the voltage down to a steady state the first time it is used after charging. Allowing the current to pass through the filament for a minute or two, until the ammeter registers a steady current, will answer the purpose.
12. A small voltmeter is very useful in charging a battery, and a suitable resistance to bring the line voltage down to that required for charging, should be included in the circuit. Either a voltmeter or a test for acid density may be used to indicate full charge.

13. *Do not fail to disconnect the charging line before turning on the filament current.*

14. Storage cell terminals are almost sure to corrode; scrape clean when connecting.

In Fig. 34 is shown the charging circuit. The resistance is usually one or more 32-candle-power incandescent electric light bulbs connected in parallel. The polarity of the plates is marked on the cell case and the connections must be properly made or the battery will be damaged. The current should flow from positive to negative through the acid. The voltmeter, if properly connected, will indicate whether or not the batteries are correctly connected to the charging line. It will be deflected in the same direction both when charging and discharging.

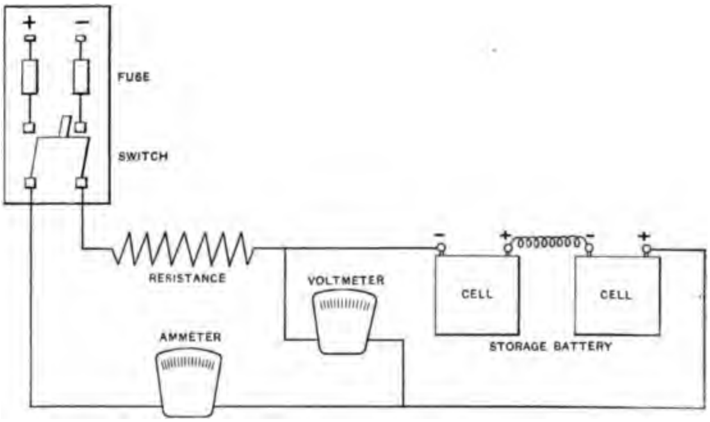

Fig. 34.—Storage battery charging. (Shearer.)

It is very convenient to have the filament and charging circuits so arranged that a switch, when making one circuit will break the other circuit. Such an arrangement is shown in Fig. 35. With this scheme the battery is always charging when not delivering current to the filament. When fully charged the switch can be left open. Referring to Fig. 35, *D* represents a stationary disk dielectric on which there is a cup-shaped conductor *C*. *L* is a non-conducting lever which, when released, allows the charging circuit to be made at *S.W*. The current then passes through the metal conductor *S*, through the battery and returns to the *D.C*. main. The lever is released by elevating the conductor *S*. When elevated the lever permits contact between *S* and *C* which makes the filament circuit. The battery, switch, etc., may be mounted on top of the protecting screen and the lever can be operated by means of a string and suitably arranged spring clamps. The rheostat and ammeter are mounted on the general switch board.

Not infrequently, when the current is turned on, the filament will fail to light. In the majority of instances this is due to poor connec-

tions. There may be a broken wire in the conducting cords leading from the high-tension wires to the filament terminal; or there may be a poor connection in the socket on the negative end of the Coolidge tube. The connections on the storage battery may be corroded. To avoid trouble of this kind keep all the wires in this low-volt circuit clean and see that all connections are well made.

Inasmuch as the two wires that conduct the low-volt current to the filament also carry the high-tension current, it is essential that the storage battery be thoroughly insulated from the ground.

While storage batteries are satisfactory they are a source of considerable annoyance and require some attention. In the first place there are the mechanical difficulties already mentioned. When the line supply is alternating it is necessary to employ some form of rectifier in order to supply the necessary unidirectional charging current. In the current range of from 3 to 5 ampères the potential drop through the filament varies from 1.8 to 4.6 volts. In other words, in a long treatment, or during a series of treatments, where there is no opportunity to charge the battery, the current gradually becomes weaker and one must necessarily adjust the rheostat to compensate this loss. This does not constitute a source of trouble nor does it interfere with accuracy, but it limits the amount of work that can be done at one time unless one provides a battery of greater capacity. Another method of providing a suitable current for the filament and one that is extremely popular among x-ray therapeutists, is by means of the step-down transformer.

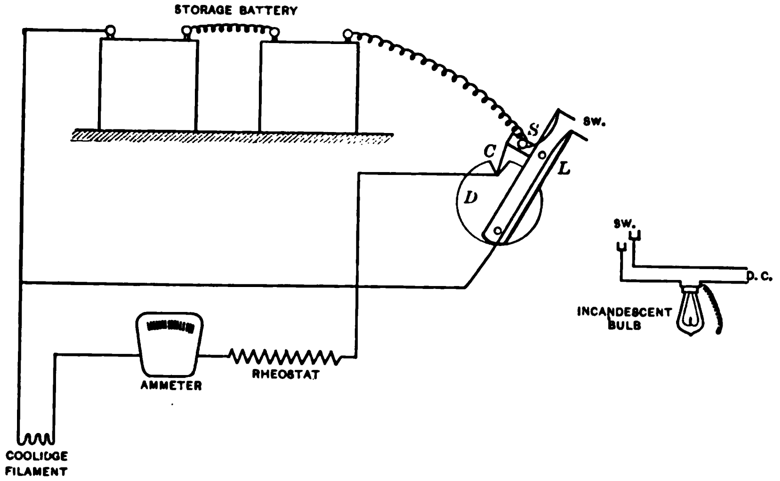

FIG. 35.—Storage battery charging circuit with connecting switch and also filament-storage battery circuit.

Step-down Transformer.—This apparatus is a closed magnetic circuit transformer in which the number of turns in the primary and secondary windings are in such relation as to reduce the voltage. The apparatus consists of an iron core around which are the primary and secondary windings (Fig. 36). The primary coil, the coil through which the "line" current passes, is composed of many turns of copper wire. The secondary consists of a comparatively few turns and is insulated from the primary. To understand the gain or loss in voltage in the induced current we may say that if the primary winding has 100 turns and the secondary has 10 turns, then the voltage in the secondary will be $\frac{1}{10}$ that of the primary. Conversely, if the primary has 10 turns and the secondary has 100 turns, the voltage in the secondary will be 10 times that of the primary. In this case the transformer would "step up" the voltage.

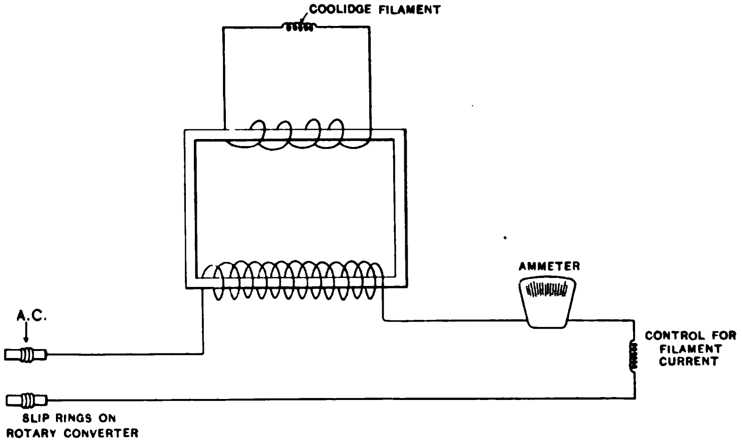

FIG. 36.—Diagrammatic representation of a step-down transformer.

If the supply is alternating it is allowed to enter the primary of the step-down transformer. If there is direct current supply the necessary alternating current is obtained from the slip rings of the rotary converter that supplies the current for the step-up transformer; or a separate small rotary converter is utilized for the purpose. A separate rotary is preferable for then the filament current will be subject only to the fluctuations in line voltage.

In the primary circuit there is some form of adjustable current control, either a series rheostat or, preferably, a choke coil. The latter consists of an iron core surrounded by a single coil of wire. The core is movable so that its relation to the surrounding coil of wire can be changed at will (Fig. 37). The control of the current by a choke coil is effected by the impedence of self inductance instead of by the resistance of a poor conductor, as is the case with a rheostat, so that

there is less fluctuation in ampèrage. It offers a quick and accurate means of controlling the filament current. As a guide to the control an ammeter is placed in the circuit.

It is not necessary to insulate the step-down transformer from the ground as is the case with the storage battery.

The only objection to the step-down transformer is that it is subject to fluctuations in line voltage but the ammeter reading can be kept steady by means of the filament control. The small rotary converter rarely causes trouble if it is occasionally inspected, oiled and kept clean.

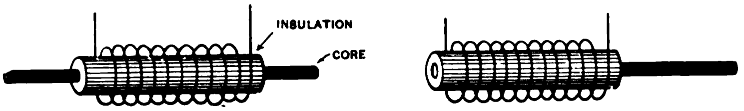

FIG. 37.—Choke coil for regulating current for Coolidge filament.

Radiator Type of Coolidge Tube (Fig. 38).—The ordinary type of Coolidge tube will operate satisfactorily on an unrectified current providing the heat of the focal spot of the target is kept below the point at which it gives off an appreciable number of electrons. If electrons are supplied at the target in sufficient numbers, and they are so supplied when the metal becomes sufficiently hot, then inverse current will pass, the anode and cathode alternating in function with the alternations in the current. The ordinary Coolidge tube must, therefore, be actuated by a rectified current. The radiator type of Coolidge tube aims to keep the target cool whereby it becomes impossible for the target to function as cathode and the inverse current is choked off. The tube is a product of the General Electric Research Laboratory. The chief features are the small diameter and the special target. The target consists of a tungsten button set in a heavy copper backing which is continuous with a large copper rod extending out of the neck of the tube. To this is attached a series of disks acting as radiators. The copper is used because it is a good conductor of heat. The tube is designed for 5 M.A. on a 5-inch spark gap for continuous duty (fluoroscopy or radiotherapy) and 10 M.A. on a 5-inch gap for diagnostic work (short exposures). Operated within these limits this

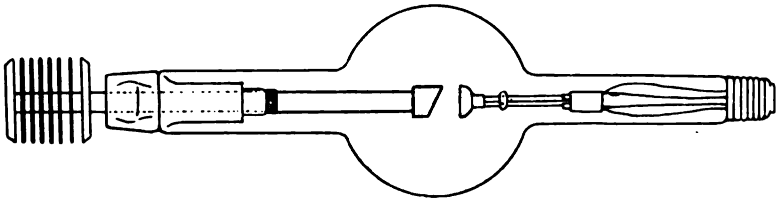

FIG. 38.—Drawing of the radiator type, self-rectifying, Coolidge tube.

tube suppresses completely each alternate half wave and therefore constitutes a self-rectifying tube.

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CHAPTER V.

APPARATUS AND TUBE CHARACTERISTICS. PROTECTION.

Operating Conditions for X-ray Tubes.—There are two fundamental principles that must be kept in mind: it is necessary to have (1) a proper supply of electrons to carry the current and (2) electrical conditions that will compel these electrons to travel from cathode to anode at suitable velocity. These two must be in such relation to each other that a proper voltage will be maintained when current is actually used. Current is the charge of one electron multiplied by the number passing per second. Current travels from high to low potential, therefore it is the potential difference or voltage drop between cathode and anode that provides the path for the electrons. Shearer explains this difference in potential as being due to a "piling up of charges and negative electrons at the target and cathode respectively and this must be done by the generator. When electrons move across from cathode to target they tend to relieve the congestion and if the generator failed to maintain the supply the voltage and charge would disappear. The greater the number of electrons passing across in a given time the more the terminal voltage will be reduced for a given ability of the generator to pump a new supply. The greater the amount of current (milliampèrage) the greater the power demanded from the generator to maintain voltage, and the more will be the drop in voltage from that shown on open circuit or on small current. When the current increases, irrespective of the type of tube used or the design of the generator, the operating voltage will be reduced unless the rheostat or autotransformer control is moved so as to apply more power to the primary. The spark gap on open circuit is no guide to the ability of the transformer or induction coil to keep up voltage when current is drawn. Inasmuch as reduced voltage very much more than offsets the effect of change of current in *x*-ray production as regards quantity and likewise decreases the ability to pass through material, the proper maintenance of voltage is the most indispensable requisite in any *x*-ray installation. By increasing exposure time nearly all work may be properly done at low current but no increase of exposure time will compensate for too low voltage."

Gas Tubes.—Tubes of this type are not suitable for modern therapeutic technic. The principal reason is that the operator has very little control over the supply of electrons. The characteristics of gas tubes vary with the construction, *i. e.*, the kind of metal used for the

target and the kind of residual gas. Furthermore, the characteristics of two apparently identical tubes from the same manufacturer will vary and, indeed, the behavior of a given tube will alter with atmospheric changes, under different electrical conditions, with use, and for other reasons. In fact every gas tube is a law unto itself, so that it becomes necessary for the operator to know the peculiarities of each one of his tubes.

A tube that is being operated on a low current has a tendency to increase in vacuum or, as it is usually stated to "harden." This means increased resistance so that more voltage is necessary for the same current or without more voltage the current will decrease. The "hardening" is due largely to absorption of gas by the metal electrodes. As the tube "hardens" more electrons can be obtained by increasing voltage (moving rheostat handle to higher readings), or by lowering the vacuum by means of the softening device. When the tube becomes hot the absorbed gas escapes from the metal electrodes and the tube "softens." As there is no way to "harden" the ordinary gas tube during operation it must be temporarily discarded. Unless the vacuum is reduced to the point where the cathode rays produce a visible fluorescence the tube will "recover" upon cooling. If the vacuum is reduced to this extent the tube is usually useless until repumped. There is a tendency for many gas tubes to be "cranky," that is, when run on low power with small current and high voltage the vacuum is likely to increase rapidly. This change in resistance causes the tube to behave in an uncertain manner. When the tendency is about balanced by release of gas from the hot target, the tube will run at a fairly uniform current and voltage for a short time. Such a tube is said to be "seasoned." New tubes and very old tubes are likely to be "cranky".

To have constant and accurate control of the quantity and quality of *x*-rays emitted it is necessary for the operator to be able to control at will the supply of electrons and their velocity. Obviously this is impossible in the case of the gas tube.

Coolidge Tube.—The Coolidge tube contains no residual gas and the vacuum never changes. The electrons are derived from the hot tungsten filament. There are no electrons until the filament is heated and without electrons current cannot pass. The electrons are driven across to the target by the potential applied to the tube. The numerical supply of electrons depends entirely upon the amount of heat in the filament. The velocity depends entirely upon the difference in potential between the cathode and anode or, in other words, the voltage applied to the tube. When the supply of electrons is large more current is carried across the terminals hence the milliampèrage will increase with the heat in the filament. Also, on account of the ease with which current passes when there is a large supply of electrons there is a drop in potential (unless more power is supplied) and consequently there is lessened velocity of the electrons. Now it will be recalled that the

quantity of radiation emitted depends upon the number of electrons bombarding the target in a given unit of time while the quality (wave length) depends largely upon the velocity of these electrons. It will be obvious, then, that quantity and, to some extent, quality depend upon the amount of heat in the filament.

These facts can be made clear by visualizing a tube in action. Assume a tube to be actuated as follows: interrupterless transformer with rheostat set on the fifth button; filament ampèrage 3.2; spark gap 7 inches, milliampèrage 2. Now add a little more current to the filament so that the ammeter reads 3.5; the spark gap drops to 6 inches indicating that the x-rays are less penetrating; the milliampèrage will increase to 3 which means that more current is passing through the tube, more electrons are being supplied and, therefore, there is an alteration in the radiation emitted. The above figures are arbitrary. It is important to note that when, with a definite setting on the rheostat or autotransformer, more current is applied to the filament, there is a drop in voltage and an increase in milliampèrage. The potential under these conditions can be increased only by shifting the control handles to higher readings. But moving the rheostat or autotransformer handle to a higher reading will not necessarily cause more current to pass through the tube. If the amount of current is greater than the available supply of electrons can carry, the excess will spark across the alternate gap. Sparking at the parallel gap simply indicates an amount of current in excess of the saturation point of the tube and does not interfere with accuracy. From the foregoing it should be obvious that for any given filament current there is a maximum tube current—this is known as the saturation current. After the saturation current is reached increasing the voltage will not increase the tube current. The only way the tube current can be increased is to add more heat to the filament and obtain a higher saturation current. This is quite different from the gas tube where a higher voltage produces greater tube current.

When in action, with the exception of very mild currents, the target of the Coolidge tube becomes cherry red, then bright red, then white heat and finally luminescent. This heating of the target has no deleterious effect and does not modify either the quality or quantity of radiation emitted. It is possible, of course, to spoil a fine focus tube with a heavy current; but in therapeutic work it is seldom necessary to employ over 10 milliampères and with this amount of current the tube will run for hours with the target at white heat without harm resulting. The Coolidge tube does not fluoresce when in operation.

Unlike gas tubes there is no difference in the behavior of various tubes of the Coolidge type—what one will do, so will another.

There is a little variation in the conductivity of the filaments of different tubes. For instance three Coolidge tubes were tested on a storage battery circuit with a fixed rheostat setting—the readings in ampères were as follows: 3.45; 3.65; 3.65 respectively. This is of no practical importance as it requires only a slight adjustment of the

filament control to obtain the proper spark gap and milliampère readings and these are the deciding factors in governing technic. In this connection it is not safe to judge tube current by the ammeter in the filament circuit for the reason that a very slight increase in filament current causes a very large increase in tube current.

All tubes become darkened with use, but in the case of the Coolidge tube this coloring of the glass does not alter the characteristics of the tube. The Coolidge tube has a very long life. Handled with care it can be used for hours daily for a number of years. The target can be injured by very heavy currents especially if there is a fine focus, and occasionally one of the electrodes, usually the anode, may become loosened.

In a few instances the white hot target of a Coolidge tube has broken off during a treatment. In a personal communication Dr. Coolidge states that this accident has never occurred when there was a mechanical joint between the molybdenum stem and the tungsten head of the target. For a while during the war it was necessary to electrically weld the head of the target to the stem. All complaints have been made in connection with tubes constructed in this manner. All tubes now possess the mechanical joint. Whenever a tube with a welded joint is returned to the manufacturer for any reason the joint is changed to the mechanical type. The mechanical joint is easily recognized as it shows a distinct line (depression) between the two metals, while the joint in the welded anode can be made out only with difficulty.

The chief value of the Coolidge tube in therapeutic work lies in the ability of the operator to control easily and accurately the supply of electrons; also that the supply of electrons is independent of voltage.

Bedside Unit and Radiator Tube.—The bedside unit is an ingenious apparatus and it has been used extensively and almost exclusively for diagnostic work. Recently it has been advocated for therapeutic purposes but for this kind of work the apparatus is in the experimental stage. Working with direct current and the U. S. Army bedside unit the author has thus far been unable to standardize an indirect technic. It is probable that this or similar apparatus will be so constructed in the near future as to answer the necessary requirements of roentgen therapy. The oil-immersed generating outfit described in Chapter III is also in the experimental stage.

The characteristics of the radiator tube are the same as those of the ordinary Coolidge tube with the exception that when operated on the current for which it was designed the target does not become visibly heated. It is not heated sufficiently for liberation of electrons and without such electrons inverse current cannot pass. It is unnecessary, therefore, to use a rectified current.

Induction Coil.—Coils supply a current of high voltage but the output is limited. This limitation depends upon the construction of the coil, the inability of most interrupters to function properly on heavy current and the fact that only the break current is utilized. When a tube

is running on a low resistance it is possible to obtain a milliampèrage of 15 or 20. On high resistance, however, it is difficult to obtain coils that will force more than 8 or 10 milliampères through the tube. This limitation in power is annoying in deep therapy although it is not a handicap in superficial work.

One of the most serious objections to a coil is the inverse current, a feature that is exceedingly difficult to overcome. Inverse current in therapeutic work may give rise to serious errors in dosage as a small amount of such current will interfere with the proper reading of the milliammeter. Also, it prevents the proper action of the tube and injures the latter both temporarily and permanently.

Another annoying coil characteristic is the fact that with the exception of certain interrupters that are difficult to obtain in this country, there is no way of knowing the number of pulsations per second nor can one depend upon a constant rate of interruption. In addition, most interrupters are a constant source of trouble and are unreliable for accurate therapeutic work. If one depends entirely upon the direct (pastille) method of measurement it is possible to employ a coil outfit with a certain amount of satisfaction although not without a lot of trouble; but such an outfit, in the light of modern knowledge, is not suitable for the indirect technic where electrical measurements alone are depended upon to estimate the dose.

Interrupterless Transformer.—The transformer provides a high-potential, pulsating, unidirectional current with a fixed rate of pulsation. Therefore there is no inverse current to interfere with the action of the milliammeter and the tube. There is no uncertainty regarding the number of pulsations per second; furthermore, both alternations of the alternating current are utilized. From a practical standpoint the output of the apparatus is unlimited. Even with a 9-inch spark gap (high tube resistance) it is possible to drive heavier current through the tube than is ever used for therapeutic purposes. This, of course, permits very rapid work when necessary or desirable.

One of the most valuable features of the interrupterless transformer is the accuracy and ease with which its current can be controlled. Occasionally some part of the apparatus gets out of order, but these troubles seldom occur and are easily detected and remedied. Let us assume an interrupterless transformer with rheostat control and a Coolidge tube outfit consisting of a step-down transformer and a choke-coil control. The controls are adjusted so that there is a 7-inch spark gap and 2 milliampères of current. If the motor and the other parts of the apparatus are in good condition and if the connections (especially those in the filament circuit) are well made, these two constants will be maintained for hours at a time insofar as concerns the apparatus. As a matter of fact the milliampèrage and consequently the spark gap, may be found to vary to some extent. If the capacity of the line is sufficient to carry the required current, if all connections in the high-tension and filament circuits are well made and the wires

are of the proper size, clean and composed of suitable material and properly insulated, then the unsteadiness is due to unavoidable fluctuations in line voltage. As an example, every time current is used to operate the elevator in the building there is a temporary fall in voltage. A fall in line voltage naturally causes a drop in the milliampèrage and a shortening of the spark gap. If there is only an occasional small drop in line voltage lasting a fraction of a second, *x*-ray output will not be seriously interfered with but even if there is considerable fluctuation the effect is easily and accurately compensated by regulating the filament current by means of the filament control.

If one could obtain, with absolute certainty, a steady voltage it would be a comparatively simple matter to develop an accurate technic. It is for this reason that physicists and electrical engineers have labored so hard to perfect an apparatus that will supply a constant voltage. Unfortunately there is no automatic device that will keep the line voltage constant or compensate for line fluctuations.

We have already (p. 66) discussed the autotransformer. The autotransformer is a much better control than is the rheostat for reasons already given, but it is not of much practical value in superficial therapy where extreme penetration is not an essential feature and where only mild current is employed. This is especially true if the filament current is steady. In deep therapy (heavy current and extreme penetration), or where the filament current is unsteady, the autotransformer is of distinct value. On the other hand there is the added danger of severe or even fatal electrical shock when the autotransformer is substituted for a rheostat. It is to be noted that the autotransformer does not compensate fluctuating line voltage.

It is obvious that the filament current must be steady. We have already considered the storage battery (p. 86) and the step-down transformer (p. 90) as sources of supply for the filament current. For a time the storage battery was employed exclusively for this supply but for therapeutic purposes a properly constructed step-down transformer system gives less trouble and with the exception of faults in line voltage, is equally steady. If the alternating current for the step-down transformer is obtained from the slip rings of the rotary converter, the current will be subject to fluctuations in line voltage and to fluctuations of current from the rotary. As an example, imagine a Coolidge filament to be heated by a current from a step-down transformer connected with the rotary converter. The ammeter reads 3.5. Now when current is passed into the *x*-ray transformer there will be a temporary drop in the filament current as indicated by a lower reading on the ammeter.

This fault can be overcome to some extent by the use of the so-called "booster." A "booster" is simply a small induction coil so constructed that the relationship between the core and the primary winding can be altered at will. It is very much like the choke coil (p. 91)excepting that the "booster" has a primary and secondary winding while the

choke coil has but one winding. The "booster" is placed in the circuit so that one winding is in series with the primary of the x-ray transformer while the other winding is in series with the primary of the step-down transformer. Now, when the main switch is closed and current enters the primary of the x-ray transformer, current also enters the primary of the "booster," where it is stepped up in voltage and passed on to the filament transformer. In this manner the loss of voltage in the filament circuit that occurs with the closing of the x-ray switch, is compensated. After the first rush of current very little if any current enters the "booster" so that it only functions at the closing of the x-ray switch. It is essential that the "booster" be properly constructed for, or in "tune" with, the apparatus to which it is to be connected; also that the connections are correctly made and the core properly adjusted. One should bear in mind that the "booster" simply prevents a drop in voltage when the motor suddenly receives a heavy load. It does not compensate fluctuations in line voltage. There is no way to compensate for fluctuation in line voltage excepting by changing the filament current by means of the filament control.

As explained in Chapter IV there are two methods of providing suitable current for the Coolidge filament, namely, the storage battery and the step-down transformer. With the latter we have already seen that, where there is a D.C. supply, the current can be obtained from the slip rings of the x-ray rotary or from a separate small rotary converter. The separate rotary is preferable unless a properly adjusted "booster" will prevent a drop in voltage when the x-ray switch is closed. If the supply is alternating, current is obtained directly from the main and is subject only to line voltage fluctuation. For very accurate work many operators prefer storage batteries in spite of the trouble they cause and the care they require.

When the filament is connected to a storage battery, directly after recharging, there is a rapid initial drop in the current and it is advisable to allow the current to pass through the filament until the ammeter indicates a steady flow before attempting accurate adjustment. This usually requires two or three minutes, after which the drop in the current will be exceedingly slow and will require only an occasional slight readjustment of the rheostat in the filament circuit. There is no fluctuation of the ammeter reading when a storage battery is employed providing the batteries are in good condition, all connections tight and all wires clean and of the proper material.

Spark Gap.—The spark gap by providing an alternative path for the current acts as a safety valve for the coil or transformer (p. 55). In a similar manner it affords a certain amount of protection against electrical shock because if the tube fails to take current, the current will arc across the spark gap unless it can find a path of less resistance.

From a technical point of view the most important feature of the spark gap is that its length indicates the voltage of the secondary or tube circuit and this in turn signifies penetration or wave length. Very

few practical operators express penetration or wave length in terms of voltage (kilovolts) but instead give the length of the spark gap in inches or centimeters. Confusion has been caused in practical work by the fact that there is a difference in value when comparing the spark gap of a coil with that of an interrupterless transformer. For instance, with a given milliampèrage, the voltage or penetration is greater with a 7-inch coil gap than with a transformer gap of equal length. This can be readily understood by recalling that the plotted current from an induction coil consists of a series of abrupt waves with very sharp peaks. It is only at the summit of these waves, at the very highest potential, that sparks jump across the gap. In the case of the rectified current from a transformer the waves are less abrupt, the peaks are blunt and the current traverses the spark gap from a lower potential level. Between two interrupterless transformers, however, even of different makes, there is little if any variation in spark gap values provided the spark gaps themselves are similarly constructed.

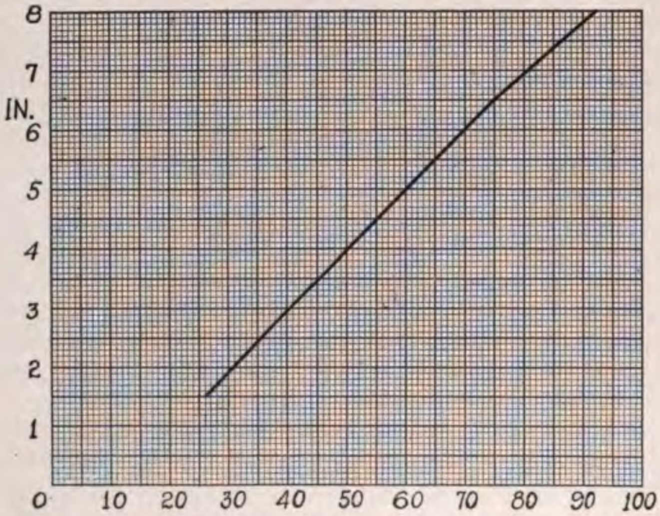

Chart 11.—Approximate relation between effective kilovolts and spark gap for moderately blunt points. (Shearer.)

Unfortunately spark gaps have not been standardized. Most transformers are provided with sharp-pointed gaps—a few are equipped with blunt points. The varieties in spark-gap design is of some technical importance. Sparks jump a little more readily from points than from blunt ends and much less readily from balls. If spheres are employed the value will vary with the size. Therefore, in recording the length of a spark gap it is essential that the character of its points be given. Spark gaps should be kept well polished and free of dust and moisture.[1]

Chart 11, borrowed from Shearer, shows the relation between kilovolts and spark gaps between blunt points.

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[1] H. J. Ullmann (Am. Jour. Rœntg., 1921, viii, n. s., p. 195) suggests a sphere gap as a standard.

PROTECTION.

In considering this important question we must discuss methods of protecting both the operator and patient not only from the injurious influence of *x*-rays and radium, but from the danger of electrical shock.

Electrical Shock.—Shearer says that "in the use of high power *x*-ray apparatus care must be taken to avoid discharge from the high tension lines to earth through the body of either the patient or the operator. Fatal results may follow, and in any event the nervous shock to the patient may be serious. Danger arises from sparks followed by an arc discharge from the high voltage line to the body—hence to the earth. To get such a discharge there must be:

"1. Grounding of the patient or contact with badly insulated material.

"2. So short an air distance from some part of the high-tension system as will allow a break over spark.

"A single spark, while disconcerting, is not dangerous to life but it serves to pave the way for a heavy discharge from the line if the supply is maintained. On most induction coils body connection so reduces the line voltage as to preclude any fatal amount of current, but with the modern high-power transformer it is a different matter.

"The danger of an initial spark over to the body is solely a matter of line to skin distance and voltage from line to earth. When a tube is taking current the voltage from either line to earth is less than it would be on the same control setting if no current were passing. Hence, failure of the tube to take current at any time tends to cause discharge to the patient. The following are the common ways that this might happen:

"1. Failure to complete the high-tension connection.

"2. 'Cranky' gas tube.

"3. Failure to pass current through the Coolidge filament before turning on the high-tension circuit.

"4. Break or disconnection of Coolidge filament circuit while running.

"5. Attempting to pass current through the Coolidge tube in the wrong direction."

Another cause for a spark over is the high-tension surge often caused on closing the primary switch of the transformer. This, however, is usually overcome by an incandescent lamp properly placed in the circuit by the manufacturer of the apparatus.

All high-tension lines should be kept at least twice as far from any portion of the patient as the length of the working spark gap. Thus if using an equivalent gap of 6 inches allow no wire closer than 12 inches. A grounded metal or conducting screen between the patient and the high-tension line is complete protection for the patient. Thus a patient lying on a grounded metal table is safe if the tube is under the table but when the patient is between the high-tension line and a grounded metal or conducting table danger is greatly increased. For

therapeutic work it is preferable to employ wooden tables containing no metal excepting in the hinges for the drop leaves.

Much has been said of the relative danger with the various controls. Simply stated it amounts to this: the rise in voltage when the tube fails to take current is very much greater on a resistance control (rheostat) so that the chance of an initial spark is greater; but after such spark the chance of a following arc is reduced by reason of the resistance in the primary circuit offered by the rheostat. With autotransformer control, or operating without resistance, *i. e.*, with rheostat all out, the rise in voltage on open circuit is less; but if an arc is started it is very dangerous. A quick-acting overload primary break is very desirable (Shearer). It is well to bear these points in mind for several people have been injured and a few killed by ignoring these simple rules (Jaugeas).

X-ray Protection.—The patient must be protected against an overdose in a circumscribed area, and from too much radiation being applied to large areas of the body surface. The dangers of these errors and the methods devised to avoid them will be dealt with in subsequent chapters. Suffice it to say here that it is inadvisable to allow the rays to come in contact with any more of the cutaneous surface than requires treatment. The tube is usually placed in a shield of some kind. This may consist of a lead-glass bowl or a suitably lined box which is capable of preventing the passage of but a small percentage of the radiation. The bowl or box will afford ample protection for the general body surface. The inferior surface of the tube shield is provided with an adjustable diaphragm which can be regulated so that the beam of rays is the exact size of the lesion to be exposed. In addition, it is customary and advisable to protect the part immediately around the lesion (6 or 8 inches all around the lesion) with lead foil ($\frac{1}{32}$ to $\frac{1}{8}$ inch thick, depending upon the quality and quantity of radiation used), through which a hole the size and shape of the lesion may be cut. It is especially necessary to shield very carefully all hairy parts such as the eyebrows, etc. Not infrequently patients complain of a disagreeable sparking from the lead foil. This is especially noticeable when high voltage is being used and is presumably due to induction. The sparking can be avoided by having a good contact between the lead and the skin or having these parts separated by a non-conductor such as thick rubber sheeting. Another satisfactory, and perhaps the best method of avoiding this annoying feature is to ground the lead foil by connecting it to a convenient water pipe. If this method is followed one must be certain that the patient is never placed, by any possible chance, between the high-tension line and the grounded material. It is possible to obtain flexible or plastic material that is fairly impervious to the *x*-rays, that is not a conductor or at least is a very poor conductor, and which does not give rise to the sparking mentioned above (Cumberbatch; Gorton). This material can be purchased in sets which contain pieces that are square, oblong, semicircular, etc. By correct adjust-

ment of pieces of the proper shape, the skin around a lesion of any size or shape can be adequately protected.

The operator is not and should not be exposed to the direct beam. In therapeutic work it is occasionally necessary for an assistant to remain close to the tube for the purpose, for instance, of holding the head of a nervous child. When this happens the hands should be encased in "protection" gloves, the body covered by a "protection" apron and the tube placed in an efficient shield and so adjusted that the assistant is behind the target. But no matter how much care is exercised, the assistant must not be exposed in this manner at frequent intervals. It seems superfluous to add that the operator should never employ his hand for the purpose of casting a shadow on a fluoroscope.

When a tube is in action there are more or less rays all over the room in spite of the tube shield. The patient is exposed to these indirect rays a comparatively few times; never often enough to effect injurious results. But the operator is likely to be exposed daily—hourly—for weeks, months and years. Therefore, in addition to the tube shield, he should stand behind a wide, tall lead screen (covered with lead from $\frac{1}{16}$ to $\frac{1}{4}$ inch thick and containing a lead-glass window). It is preferable to have the screen as far away from the tube as possible and to have the anode always pointed away from the shield. Some operators use a three-piece screen, others remain in a lead-lined booth, while still others stay in another room which is separated from the operating room by a lead-lined wall furnished with a lead-glass window. The controlling apparatus is, of course, placed behind the screen. The degree of protection of this kind that is necessary depends upon the amount and type of work done. For a moderate amount of cutaneous therapy a single-piece screen 6 feet high and 3 feet wide, placed at least 6 feet from the tube and lined with lead $\frac{1}{8}$ inch thick will afford ample protection. A photographic plate placed behind such a screen and suitably protected from light will likely be fogged in a few days, weeks or months. This need occasion no alarm for the fogging is due to scattered and secondary rays which on account of small quantity effect very little biologic action. Protection screens as above described have been employed for years and have stood the test of time. The author has examined operators who have done both deep and cutaneous therapy many hours daily for periods of from eight to fifteen years, protecting their persons in accordance with the scheme outlined above, and failed to find any injury to the skin, blood, testicles, or lymphoid tissue.

It is important to test all the joints and the lead-glass window of the protection screen or booth with a fluoroscope to see if there are any leaks.

Radium.—Physicians are extremely careless in their handling of radium. This carelessness has been brought about by a feeling of security that is apparent rather than real. As will be seen in subsequent chapters radium will effect the same acute, subacute and chronic

cutaneous reactions and the same changes in the internal organs as will the *x*-rays. It will not do for the operator to remain day after day in a room in which radium is being administered. The dose received by the operator at long range is indeed small, but the effect is cumulative and after several years injury may result. In dermatological practice the physician is not likely to use more than 25 mg. or 50 mg. of radium element for any one application. When this is applied to a lesion the area can be covered with heavy lead foil and the patient allowed to sit in a distant corner of the room. Whenever possible the applicator should be strapped on or held on the part by the patient. If it is to be held by the operator or assistant a long handle (2 to 4 inches) should be provided for the purpose. Flat applicators might well be backed with a layer of lead. The greatest danger to the operator lies, possibly, in the frequent handling of the radium with the fingers. When preparing an applicator for a treatment care should be taken never to allow the fingers to come in contact with the active side of the applicator. Forceps should be used. An unscreened flat radium applicator ½ inch square and containing 10 mg. radium element is capable, when held in contact with the skin, of effecting an erythema as a result of an exposure of a few minutes. Repeated short exposures may cause any or all the symptoms found in the chapter on *x*-ray and radium reactions. We now know, by very sad experiences, what carelessness cost the pioneers in *x*-ray work. It is to be hoped that the same lesson will not be required in connection with radium.

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CHAPTER VI.

INSTRUMENTS FOR MEASURING *X*-RAY DOSAGE. PHOTOGRAPHIC METHOD.

THE first instruments to be considered are the ammeter, milliammeter, voltmeter and kilovoltmeter. It is not advisable in a book of this kind to describe the detailed construction of these instruments, although the radiologist should be familiar with both their construction and theory of action. They are all modified galvanometers. A galvanometer is an instrument which measures current by electromagnetic action. It will detect current and will determine its direction, strength, and voltage. The principle of construction of galvanometers is based on the fact that a magnetic needle is deflected by the influence of the magnetic field which exists around the conductor carrying an electric current. The simplest instrument consists of a magnetic needle delicately suspended in the center of a coil of wire. When this coil is connected in a circuit through which an electric current flows, a magnetic field is created and the needle is deflected. A scale, calibrated or graduated in degrees, is employed to determine the amount of deflection. The sensibility of a galvanometer depends upon the construction of its coil (number of turns of wire, size of wire, etc.) the distance of the needle from the coil, the weight of the needle and its ability to move freely. There are two main types of galvanometers: First, are those in which the magnetized body is movable and the coil is stationary; second, in which the magnetized body is stationary and the coil is movable. It is to the latter type that the well-known d'Arsonval milliammeter belongs. A galvanometer with a "long" coil, *i. e.*, many turns of wire of high resistance, will measure fall of potential and when such an instrument is calibrated in volts or kilovolts it is called a voltmeter or kilovoltmeter. "Short" coil galvanometers of low resistance can be calibrated in ampères or milliampères and are then known as ammeters and milliammeters.

Ammeter.—This is an instrument to measure the amount of current in the low-tension circuit, *i. e.*, the current passing into the primary of the coil or the interrupterless transformer. It is seldom supplied with interrupterless transformers although it is usually found on the switchboard of a coil outfit. It does not indicate what the operator must know, namely, the milliampèrage of the secondary or tube circuit. It is not a necessary factor in establishing a radiotherapeutic technic. It is useful, however, in establishing a relation between the primary and secondary current. If, for instance, the primary ampèrage increases

considerably and there is a marked diminution in the secondary current, one knows that there is something wrong with the apparatus. But this information can be ascertained without the aid of the ammeter. An ammeter in the Coolidge filament circuit is useful but not necessary.

Milliammeter.—This is an absolutely essential instrument of precision. The quantity of x-rays is in proportion to the amount of current passing through the tube, and the milliammeter registers this current. The instrument is connected in the secondary circuit. The fact that it must be so connected is somewhat of a disadvantage because it is sometimes inconvenient to place it close to the operator and when it is mounted at a distance rapid and accurate readings become difficult. A milliammeter is now being perfected that is connected in the middle of the grounded secondary circuit of the interrupterless transformer. This meter can be mounted on the switchboard with the other meters, and therefore is more convenient and more easily read. It is not susceptible to induced currents and gives less trouble than the milliammeters now in general use.

The radiologist must be acquainted with all possible errors in the milliammeter readings. In the first place it should be realized that the milliammeter records the current that is passing through the secondary or high-tension circuit; not necessarily only the current that is going through the tube. If, therefore, there is a leak in the circuit (brush or effluve discharge from high-tension wire to a grounded conductor such as a water pipe, etc.), this lost current which, of course, plays no part in the production of x-rays, is nevertheless recorded by the milliammeter (see articles on losses of transmission by Shearer and Van Zwaluwenburg).

Another cause for inaccuracy is the inverse current which has already been considered (p. 56). If the instrument is not properly insulated, or if dust is allowed to accumulate on the cover, induced currents may interfere with its action. Meters should be tested occasionally with a standard milliammeter. The author has five milliammeters, one for each of four interruptless transformers and one for a control. Each of these meters is compared with the control every three months and occasionally one or more meters will be found to differ from the control. On the other hand the five meters sometimes read the same for many months. A slight adjustment of the suspended needle or a drop of oil properly placed, or a thorough dusting, or better insulation will usually remedy the trouble when a meter fails to register the same as the control. The control meter should be tested by an expert occasionally. New meters are more likely to undergo spontaneous change than are very old ones, therefore an old meter is preferable for the control instrument. The point to be emphasized is that the operator must be certain that the milliammeter is functioning properly. When, in giving his technic, an operator states that he employed a current of 2 milliampères the statement must be accurate, otherwise how can a technic become standardized and universal?

Most milliammeters contain a double scale. The upper scale is calibrated for heavy currents and reads from zero to 50 or 100 milliampères. The lower scale is for mild currents and registers from zero to 5 or 10 milliampères. With this calibration it is possible to read accurately fractional parts of a milliampère, a matter of importance in cutaneous roentgenotherapy. A switch is provided which enables the operator to shift from one scale to the other. It is very important that the meter be of the dead-beat type—that is, the needle registers current instantly and remains absolutely steady until the current is increased or decreased.

The milliammeter also serves as a polarity indicator. With a gas tube polarity is readily shown by the appearance of the tube. Correct polarity results in a uniform color while inverse current produces a series of rings. With a Coolidge tube the milliammeter serves as a guide, for no current will flow through the cold tube in the inverse direction. If the meter registers the polarity is correct.

Kilovoltmeters.—The kilovoltmeter registers the voltage in the secondary circuit. It indicates the potential that is applied to the tube—very important information. Kilovoltmeters are not in wide use at present because the instrument has not been very practical and most operators have preferred to depend upon the spark gap for information relative to voltage. The kilovoltmeter for practical workers is connected in the low tension circuit and is calibrated by means of the spark gap. The main trouble with the instrument is that it registers the voltage of a current of only one strength. That is to say, if the meter was calibrated in connection with a current of 2 milliampères in the secondary circuit, it will not register accurately with any other milliampèrage. An instrument is now being perfected which is connected in the middle of the grounded secondary circuit of the interrupterless transformer (alternating low-tension current). This meter is also calibrated via the spark gap but it is independent of the load—*i. e.*, it registers correctly regardless of the milliampèrage. It is to be hoped that the instrument will be standardized; that is, that the calibration will be made with a standardized spark gap, otherwise it is going to be difficult to perfect a universal technic. The advantage that this instrument will have over the spark gap is that by means of a scale of figures and a quick-acting, dead-beat pointer, instantaneous and accurate readings can be made in kilovolts.

QUALITY.

In practical work it has been customary to employ the terms quality and quantity to denote the amount and kind of radiation employed. Quality is a question of wave length and, therefore, penetrability. The wave length being determined by the potential applied to the tube allows quality to be expressed in terms of kilovolts or spark-gap lengths. It is preferable, excepting when speaking in very general terms, to

[illegible] or rays. Instead [illegible] the spark gap. [illegible] by direct measure[illegible] radiometers, etc. In [illegible] employed to indicate an [illegible] photographic or fluoro[illegible] signifies an instrument to [illegible] or by the pastille method. [illegible] connection only with instru[illegible] means. Most of these instru[illegible]

[illegible] **Penetrometer.**—This instrument is [illegible] Two metals of different atomic [illegible] aluminium have different absorption [illegible] more rays to penetrate its mass than

[illegible]

FIG. 40.—Roentgenogram of Benoist penetrometer.

[illegible] the ratio between the permeability of [illegible] with the penetrating power of the x-rays. [illegible] arbitrarily, that aluminium is five times [illegible] "soft" rays; it will be ten, twenty or thirty [illegible] for rays of greater degrees of penetration. [illegible] aluminium for his instrument because the [illegible] varies comparatively little with increased [illegible] permeability of aluminium increases markedly [illegible] is ascended.

[illegible] of a central disc of silver, 0.11 mm. thick, [illegible] of aluminium whose thickness varies from [illegible] The arrangement, as shown in Fig. 39 suggests [illegible] 1 is 1 mm. thick; sector 12 is 12 mm. thick. [illegible] either by making a roentgenogram of the [illegible] by means of the fluoroscope. Inasmuch as [illegible] be made very often, it is preferable for sev-

eral reasons to depend upon the photographic method. Fig. 40 is a roentgenogram of the Benoist penetrometer. It will be seen that the aluminium sector No. 6 corresponds in half-tone (depth of shading) to that of the central silver disc. Radiation that will produce this reading is known as Benoist 6. Very "soft" rays are indicated when sectors 2 and 3 correspond to the central disc; 3 or 4, "soft" rays; 5 and 6, "medium;" 7 and 8 "hard;" 9 to 12, very "hard." In studying the roentgenograph, comparison will be facilitated by employing a diaphragm of black paper or cardboard in order to isolate each sector at will. When the fluorescent screen is used the diaphram is composed of lead. It should be remembered that the primary beam of *x*-rays is not homogeneous; it is composed of rays of varying wave length or penetrability. The Benoist penetrometer indicates the average penetration, not the maximum nor the minimum. In other words, when the instrument registers No. 6 the beam is composed mostly of rays of this quality but there are also more penetrating and less penetrating rays present.

Shearer, by very carefully conducted experiments, has compared the Benoist instrument with a fairly blunt spark gap. The work was done with an interrupterless transformer, a special high-tension voltmeter and a Coolidge tube. The results were as follows:

Benoist. Readings.	Kilovolts.	Spark gap. Inches.
3	15	1.3
4	25	2.3
5	35	3.2
6	44	4.0
7	53	4.9
8	60	5.5
9	70	6.5

The above values are probably a little less than those found for breaking voltages in some cases since the voltmeter used reads effective voltage for a sine wave while the spark gap measures "peak" voltage. On page 100 there is a chart that shows a higher voltage value for break-over sparks on a blunt gap.

As we approach perfection and standardization of apparatus and technic the penetrometer becomes of less importance and is less frequently used. Formerly most operators expressed penetration in terms of some penetrometer, now it is in spark-gap lengths. The penetrometer most commonly employed in this country is the one already described. But there are other penetrometers a brief description of the most important of which is herewith given.

Walter Penetrometer.—This instrument consists essentially of a sheet of lead in which there are eight small holes. The holes are covered with platinum foil whose thickness varies geometrically from 0.005 mm. to 0.64 mm. A rœntgenograph may be taken of the instrument or it may be mounted on an adjustable fluoroscope supplied by the manufacturers. When exposed to the *x*-rays some of the holes become

visible on the screen, the number depending upon the quality of the rays. The degree of penetration is indicated by the visible hole with the highest cypher.

Walter-Benoist Penetrometer combines the good features of the two instruments. It consists of a series of aluminium apertures of various thicknesses which are covered with a thin layer of silver.

Wehnelt Penetrometer (Cryptoradiometer).—This consists, according to Knox, "of a wedge-shaped aluminium strip and alongside this a flat silver strip, both of which can be moved by means of a ratchet over a brass plate provided with a thin slit. The apparatus is adjusted until both strips show the same degree of brightness on a fluorescent screen. A scale indicates the position of the aluminium strip, *i. e.* the penetration of the rays."

In employing these instruments by the fluoroscopic method the operator must be protected. For this purpose the tube is placed in a suitable shield provided with a small diaphragm; the fluoroscope is protected by a lead face with a central aperture for the fluorescing screen; the latter is backed with thick lead glass.

COMPARATIVE PENETROMETER SCALE.

Benoist	1	2	3	4	5	6	7	8	9	10
Walter	1	1–2	2–3	3–4	4–5	5–6	6–7	7–8		
Wehnelt	1.5	3	4.5	6	7.5	9	10.5	12	13.5	15

Bauer Qualimeter.—The so-called qualimeter is an instrument that was rather extensively used before the advent of the Coolidge tube. It is a static electrometer and condenser and gives some indication of the potential in the secondary circuit and hence the quality of the rays. The instrument is not reliable as the readings will vary somewhat under different atmospheric and electrical conditions and, also, it is not "dead-beat." Essentially the qualimeter consists of two thin metal discs which are so arranged that they swing freely between two fixed metal plates. Both the discs and the plates receive a charge of like sign and, therefore, a repulsion occurs, the degree of repulsion depending upon the voltage in the high-tension circuit. This tension is indicated by a pointer (needle) and a scale of figures. The calibration of the scale is in accordance with the absorption of the rays by varying thicknesses of lead. Bauer No. 1 signifies *x*-rays that are totally absorbed by $\frac{1}{10}$ mm. of lead; Bauer No. 10 indicates rays that require 1 mm. of lead for complete absorption. The scale is supposed to correspond with the Benoist penetrometer but this has not been found to be true under all conditions.

The instrument is mounted on the wall at considerable distance from all conductors and especially from high-tension wires. It is connected by a single wire (shunt) with the negative side of the high-tension system. The qualimeter is not used much today because with modern apparatus more reliable information can be obtained from the spark gap. The readings can be duplicated only when the same milliampèrage is used.

Milliammeter, Spark Gap and Kilovoltmeter.—As we have seen, the spark gap indicates voltage and therefore quality. We have also compared spark gap lengths with the Benoist penetrometer. We know that a 9-inch gap indicates approximately 100 kilovolts, that the radiation shows an average penetration, according to the Benoist scale, of B9 with a maximum penetration much higher. At least 1 mm. of lead is required for complete absorption. With each inch removed from the gap there is a drop of 10 kilovolts and a reduction of about 0.1 mm. of lead for complete absorption. It will thus be seen that the spark gap supplies all the information that can be obtained from the various penetrometers. The advantage of a kilovoltmeter is that there is a scale of figures with a dead-beat needle which permits instant and accurate estimation. At the beginning of a treatment, after voltage has been established by means of the spark gap, the milliammeter indicates whether or not the voltage is being maintained as an increase or decrease in milliampèrage is associated with a corresponding change in voltage.

QUANTITY.

By quantity is meant the amount of rays that is emitted by the tube. Quantity may be estimated by indirect (electrical) or by direct methods of measurement. Of direct methods there are two in practical use, namely, photographic and chemical (pastille). In this chapter we will consider the photographic method.

Photographic Measurement of Quantity.—This method is based upon the fact that the *x*-rays reduce silver bromide in the same manner as does ordinary light. As an example, wrap a photographic plate in black paper to protect it from ordinary light. Cover all but a narrow strip with lead and expose it to a small amount of radiation. Another strip is then exposed to an increased amount of radiation and so on until the entire plate has been exposed, care being taken not to expose a strip more than once. When the plate is properly developed there will be a series of strips of varying densities. The density depends upon the amount of reduction of the bromide of silver granules in the emulsion and this in turn depends upon the amount of radiation coming in contact with the emulsion.

The photographic method does not record the actual amount of radiation emitted from the tube nor the amount of radiation that comes in contact with the emulsion. It simply records the chemical or reducing action of the rays as they pass through the silver salt contained in the photographic emulsion. Therefore, the density values are relative but they are accurate if properly obtained. Naturally, this method has its limitations. Exceedingly small amounts and very large quantities of radiation are not accurately recorded but the range is greater than with any other direct method and it answers the same practical requirements in this respect. The results will differ, of course, in accordance with the speed and thickness of the emulsion and

with the method of development. It is possible, however, to standardize the emulsion, the developer and the technic so that results may be duplicated at will.

Physicists depend very largely upon the photographic method when they desire to utilize direct estimation either for the purpose of measurement or to obtain permanent records. It is extremely sensitive, quick and very accurate when properly done. For experimental work physicists employ photographic plates but for practical therapeutic purposes it is customary to use photographic paper (developing paper such as bromide paper, velox, etc., not printing-out paper, such as solio, platinum, etc.). The photographic method of measurement used by rœntgenologists was suggested by Stern, of New York, in 1903. Two years later Kienböck published a description of his radiometer. Kienböck's radiometer or quantimeter has been very extensively used in practice.

Kienböck Quantimeter.—This instrument consists of a wooden box containing a standard scale of photographic half-tones and a number of strips of silver bromide paper, ½ by 2½ inches, each of which is enclosed in a light proof envelope. Both the envelope and strips contained therein are stamped with the same identification numeral. On the envelope there is a label on which may be written the name of the patient, date and duration of the exposure, etc. The scale is white at one end and almost black at the other end. Between the two extremes are seven half-tones ranging from light gray to medium and dark gray to almost black. These represent the varying depth of shading assumed by the strips when exposed to different amounts of radiation. The scale is standardized and calibrated in units based on skin effects. The various shades are marked; 0, ½, ½, 4, 5, 6, 7, and 10. No. 1 is the Kienböck unit, designated 1X and it represents $\frac{1}{10}$ the so-called epilating dose; 10X, therefore, would be the epilating dose for scalp hair.

A small receptacle in which are two windows, both of which are covered with glass, slide along the scale. One window is over the scale while under the other is placed the strip after it has been exposed and developed. In this way a comparison is made between the strip and the scale, the result being read in X units. In addition to the above the outfit includes a metal stand containing four test-tubes, 2 inches in diameter and 2 inches in length. These are for the developing solutions. After a strip has been exposed to the roentgen rays it is developed in a standardized developer at a definite temperature and for a definite length of time. The formula for the developer follows:

DEVELOPER.

Stock Solution A.

Distilled water	1000 c.c.
Sulphate of soda	150 gm.
Metol (Hauff)	15 gm.

Stock Solution B.

Distilled water	1000 c.c.
Potassium carbonate	110 gm.

These stock solutions will keep indefinitely when separate, but when combined the developer deteriorates. For use add equal parts of A and B. Several strips may be developed in the same solution provided they are all to be developed within a half hour. If longer intervals occur fresh developer should be employed as old developer becomes weakened both by use and by age. The temperature of the developing solution, while being used must be maintained exactly at 18° C. Cold retards development while heat accellerates. The time factor also is of the utmost importance and differs with various lots of strips. The time is given with each batch of strips. In fact a list of directions accompanies each new lot of strips and these directions must be carefully followed. The manufacturers have found it impossible in the past to standardize the paper. For this reason a new batch of strips may not correspond with the scale supplied with the original instrument. When this happens a new scale accompanies the strips. Both the scale and the strips are marked with the same letter and care must be taken to avoid employing strips of one letter and a scale of another letter.

The photographic technic must be perfect. The chemicals must be pure, accurately weighed and dissolved in distilled water. All utensils should be of glass and scrupulously clean. The strips are to be kept in a dry, cool, dark closet which is well protected against passage of *x*-rays. If carefully kept the photographic paper may be preserved for months—it should not be used if it becomes discolored. Developing is done preferably in a well-ventilated dark room with a safe ruby light, but a developing box may be employed for this purpose.

A safe ruby light consists of an eight-candle power incandescent bulb entirely enclosed in two or three sheets of "post-office paper." All varieties of ruby lamps can be purchased at any photographic supply house. The ruby light, before being used, should always be tested. This can be done by covering one-half of a Kienböck strip with black paper and exposing the other half for ten or fifteen minutes to the ruby light. If the paper does not darken when developed the light may be considered safe. It seems hardly necessary to add that no daylight, gaslight, electric light, etc., should come in contact with the strips before and during development.

After exposure, the strip is placed in the developer, kept in motion, and timed by a stop watch. It is then transferred to clean water when it is rinsed for a few seconds and then immersed in the fixing-bath for at least one minute before exposing it to white light.

FIXING-BATH.

Distilled water	1000 c.c.
Sulphate of soda	20 gm.
Tartaric acid	10 gm.
Hyposulphite of soda	200 gm.

The strip is then rinsed in water for a few seconds. The wet strip may now be taken into the light and compared with the scale. Wet

strips are shiny and the comparison is not as easy or as accurate as when dry. Drying, however, can be accomplished in a few minutes by means of an electric fan. If one desires a permanent record of the treatment, the strip, after immersion in the fixing-bath, should be washed in running water for a half hour. Great care must be exercised to prevent contamination of the developer with the fixing solution. The novice is cautioned against careless photographic technic. Absolute cleanliness is essential. Running water is preferable for rinsing and washing. If running water is not available frequently changed stationary water may be employed.

For purposes of treatment, a strip in its envelope is placed on the skin with the label facing the skin. The strip should be directly under the target and care should be taken that no part of the treated area is closer to the target than is the strip. If fractional doses are being given it is preferable to employ two strips. One strip is exposed at each sitting and it is not developed until after several treatments have been administered. It records the total dose. An additional strip is utilized for each individual treatment. In the case of an intensive dose two strips are placed on the affected area. One strip is not developed until the termination of the treatment. A small piece of the other strip is developed at the end of the first quarter of the treatment, another piece at the end of the second quarter and so forth. In this manner one ascertains the amount of rays administered at various times during the exposures which lessens the possibility of applying a greater quantity than was intended. To avoid overdosing most operators depend largely upon electrical measurement (indirect method, p. 143) and employ the photographic method as a control.

In the treatment of cutaneous cancer and a few other skin diseases it is at times advisable and even necessary to give considerably more than 10 X. This can be done by employing more than one strip; the first strip will suffice for 10 X, the second will answer for any amount between 10 and 20 X, and so on.

The Kienböck scale is for unfiltered rays. With 3 mm. of aluminium as a filter 20X will about represent the so-called erythema dose. It is thought that the absorption of radiation by 1 mm. of aluminium about equals the absorption of similar radiation by 1 cm. of average human tissue. It is possible, therefore, to estimate roughly the dose received by the deeper tissues by employing the strips in the following manner: an aluminium "ladder" is supplied by the manufacturer. It consists of a strip of aluminium, the same size as the photographic strip, and consisting of segments which vary in thickness from 1 to 3 or 4 centimeters. This is placed in the envelope with the photographic paper and exposed to the roentgen rays. The part of the strip of paper not covered with aluminium represents the dose at the surface, the portion under the 1 mm. segment of aluminium records the dose at a depth of 1 cm., etc.

The Kienböck radiometer was never extensively employed in this

country largely because of the difficulty of obtaining fresh photographic strips. It has been used hardly at all for superficial work. Many of the men who did deep therapy employed the Kienböck method or a modification thereof, usually the latter. As a rule American-made photographic paper was employed and the scientific operator of experience made his own standard scale.

The photographic method is too useful to be entirely discarded. It is to be hoped that American manufacturers of photographic material will be able to produce a reliable photographic radiometer.

REQUIREMENTS.

1. Paper strips must be fresh and standardized.
2. Scale must also be standardized.
3. Strips are to be kept in a cool, dry, dark place free from *x*-rays or radium.
4. Developer must be accurately made; only fresh developer can be used.
5. The temperature of the developer must not vary.
6. The timing of the development must be very accurate.
7. The strips must not come in contact even with feeble white light until after they have been in the hypo for one minute.
8. The letter on the strip must correspond with the letter on the standard scale.
9. Do not endeavor to estimate more than 10 X on one strip.
10. In giving a dose of 5X, through a miscalculation of the time, distance, milliampèrage or spark gap, one may find on development that 8 or 10X has been administered. Therefore, unless certain of the technic one should employ, in addition to the strip that is to record the full dose, an additional strip, parts of which can be developed at different periods during the exposure.

ADVANTAGES OVER OTHER DIRECT METHODS.

1. The method is inexpensive.
2. The photographic paper is more sensitive than pastilles, therefore it is possible to record smaller doses.
3. Unlike pastilles the strips do not fade; therefore a permanent record is made.

DISADVANTAGES.

1. No record is obtained without developing the strips, but this can be accomplished in about three minutes.
2. Wet strips are more difficult to compare with the standard scale than are dried strips, but drying can be accomplished in a few minutes by means of an electric fan, or by the use of alcohol.
3. In this country it is difficult to obtain standard strips and scales.

4. The author is of the opinion that it is more difficult to compare the strip with the standard scale than it is to compare a pastille with the scale of the Holzknecht radiometer.

5. The photographic technic must be very exact, otherwise serious errors will be made.

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CHAPTER VII.

PASTILLE AND IONIZATION RADIOMETERS.

THE first serious attempt, in practical work, to estimate quantity by direct measurement was made by Holzknecht in 1902. This was before the advent of the photographic method described in the preceding chapter. After extensive experimental work with various chemicals he decided upon a solution of salts that underwent a considerable color change under the influence of the *x*-rays. An instrument was devised (chromoradiometer) which contained a graduated color scale and several capsules filled with the solution, the formula for which was never given to the medical profession. The method, while useful, was not a success and the instrument was withdrawn from the market.

Goldstein demonstrated that solutions of lithium chloride assumed a brown color and potassium carbonate a heliotrope when exposed to the *x*-rays. Freund employed a 2 per cent. solution of iodoform in chloroform. When exposed to the *x*-rays iodin was liberated and the color of the solution was altered. These and other visible changes evoked by the *x*-rays have been employed for quantitative measurement, but the ones above mentioned failed to survive a practical test.

In 1904 Sabouraud conceived the brilliant idea of utilizing for practical purposes Villard's well-known observation that the color of double cyanide of barium changed when this chemical was exposed to the *x*-rays. Most of the early fluorescent screens employed in fluoroscopy were composed of platinocyanide of barium and the first experiments were made with small pieces of this fluorescent screen. Working in collaboration with Noiré, Sabouraud devised a simple radiometer (Fig. 41) consisting of two colored discs mounted on a piece of cardboard. One disc, Tint A, was an unexposed pastille of platinocyanide of barium, a brilliant green color, to be used as a control. The other disc, Tint B, was of an orange color, and represented the tint assumed by a pastille placed half way between the anode and the skin and exposed to the *x*-rays until an amount sufficient to effect defluvium of scalp hair without erythema had been administered. Tint B, therefore, represents the so-called and universally accepted epilating dose. And, inasmuch as the same dose will usually evoke an erythema on parts of the body other than the scalp, it has been and still is known as the erythema or skin toleration dose. Supplied with the radiometer were a dozen or more fresh pastilles, all of which matched Tint A. Sabouraud had but one thing in mind, namely,

the successful treatment of tinea tonsurans with a single application. In this he was successful and the Sabouraud-Noiré radiometer served a very useful purpose, but it possessed many weak points one of which was the absence of a graduated color scale for the administration of fractional doses. The instrument is now obsolete although the pastille method, improved and perfected by others, was until recently extensively employed.

Bordier was one of the first to create a pastille radiometer with a more versatile control index. His instrument, however, never met with popular success. Then came the radiometers of Holzknecht, Hampson, and Corbett, a detailed description of which follows.

Teinte A du réactif avant l'exposition aux rayons X.

Teinte B que prend le même réactif après une exposition aux rayons X, correspondant à la dose *maxima* que la peau humaine peut recevoir, sans qu'il s'ensuive de l'érythème, une radiodermite ou une alopécie définitive.

1° Pour que la teinte B soit exacte, le réactif doit être placé à une distance égale à la moitié de celle de l'anticathode à la peau.

FIG. 41.—Original Sabouraud-Noiré radiometer.

Holzknecht Radiometer.—While possessing serious disadvantages, the Holzknecht radiometer is unquestionably the best instrument so far devised for use with pastilles. The instrument is shown in Fig. 42. In this illustration the row of pastilles on the left side of the instrument and all the numerals with the exception of the second column from the left may be disregarded. Referring to Fig. 42, there is an oblong, hard-rubber block measuring 2 x 5 x $\frac{1}{4}$ inches. On the right side of this base is a runner (*R*) on which are two grooves, one horizontal and the other vertical. These grooves accommodate two strips of black cardboard on one end of each of which is mounted a half pastille. The cardboard strip for the horizontal groove is known as the reaction piece (*R. P.*) while the other is the control (*C*). It will be noted that the half pastilles are so mounted that when the strips of cardboard are in

their respective grooves the straight edges of the two half pastilles are in contact, thus forming a whole pastille. In other words, there is no hiatus between the half pastilles to interfere with accurate comparison. On the left side of the instrument there is a thin celluloid band, one inch wide and 4½ inches long (*C. S.*). The band is colorless at the upper end and gradually assumes a brownish or orange tint and this becomes progressively more intensive as the lower end is approached. This is the standard color index. In the center of the base of the instrument there is a column of numerals (second column from the left) reading from zero to 8; these represent Holzknecht units.

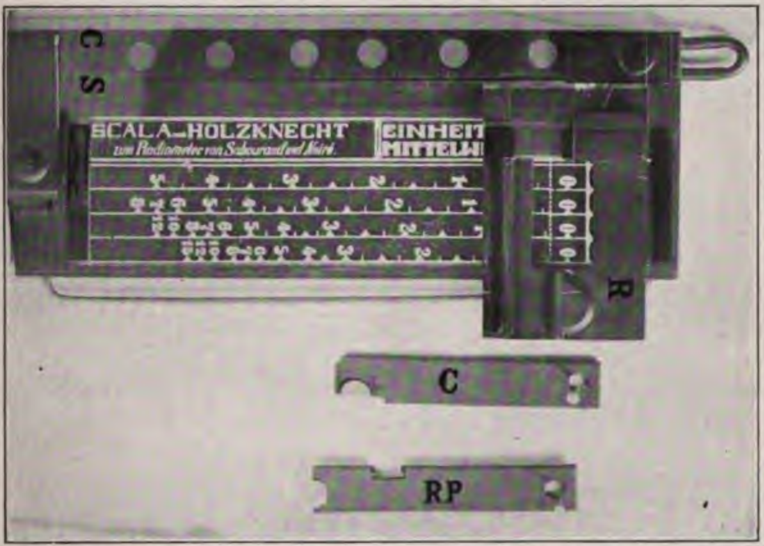

FIG. 42.—Holzknecht radiometer. cs, celluloid strip; r, sliding arm; c, control piece; rp, reaction piece.

Fig. 43 shows the radiometer with the control in place; Fig. 44 shows both the reaction piece and the control in their proper positions. The two half pastilles now form a whole pastille. It will be noted that the line of contact of the two half pastilles is exactly under the edge of the colored celluloid band. There is a piece of colorless celluloid over the reaction pastille; the refractive index of the colored band is the same as that of the celluloid covering the reaction pastille, therefore there is no difference in refraction to deceive the eye. The same photograph at *A*, depicts a small notch on the upper margin of the reaction piece, the upper edges of which are pointed and painted red; these red projections indicate the point at which a reading is to be made. In this illustration the reading is zero and it will be noted that the two half pastilles register in color exactly. In Fig. 45, the runner has been moved downward until the reading is 2H. The control is now darker

than the reaction pastille because the former is viewed through a colored medium while the latter is seen through colorless celluloid.

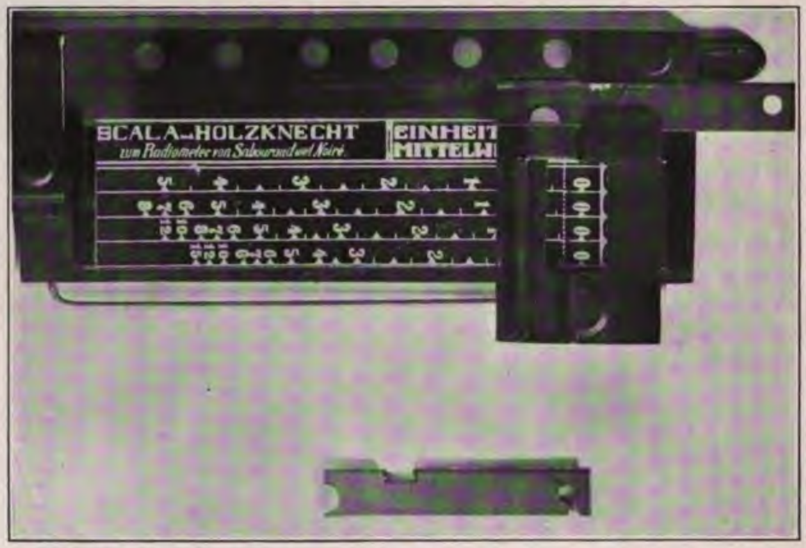

Fig. 43.—Holzknecht radiometer. Control pastille is now under the celluloid band.

If the reaction piece were to be exposed until it matched the control at this point 2 Holzknecht units would be administered.

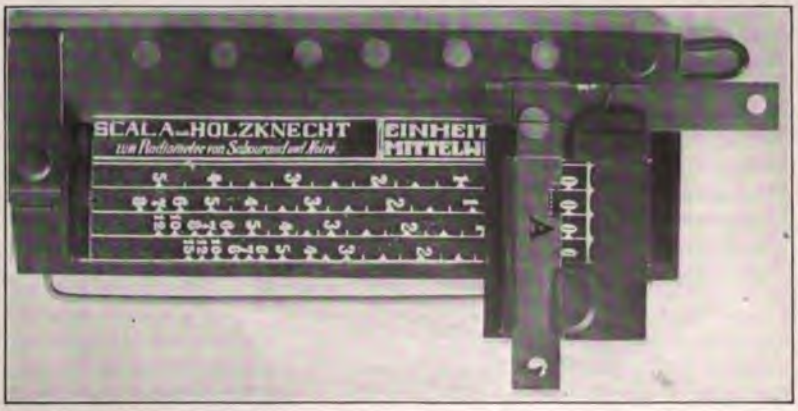

Fig. 44.—Holzknecht radiometer. Control piece and reaction piece are in position. Note that the two half pastilles form a whole pastille and that they match in half-tone.

The colored celluloid band is carefully standardized; the author compared a dozen or more new bands and was unable to detect any variation in the tints.

Holzknecht units were originally determined at half distance, *i. e.*, pastille placed exactly half way between the anode and the skin. H1 represents one-third the amount of radiation that is required to induce a mild, transitory erythema of the skin of the face of an adult male of dark complexion. H5 corresponds to Sabouraud's Tint B and, therefore, represents the epilating dose.

For reasons that will be explained later, the half distance method has been relegated to the past; the pastille is now placed on the skin (full distance; skin distance; skin-focal distance). Because of the law—intensity varies inversely as the square of the distance—the pastille, when placed on the skin, will receive four times less radiation and, obviously, will acquire four times less color. Therefore, to estimate Holzknecht units with the pastille on the skin it is necessary to multiply the reading by four. For instance, a reading of H1, obtained with the pastille on the skin, represents 4 Holzknecht units; H1¼ at skin distance is the epilating dose, etc.

FIG. 45.—Holzknecht radiometer. Sliding arm has been moved down to a reading of two units. Note that the control pastille is darker than the reaction pastille.

How to Use the Holzknecht Radiometer.—An unexposed reaction piece is removed from the humidor, enclosed in a thin, black-paper envelope and fastened to the skin with a tiny piece of zinc plaster or courtplaster. The anode is placed directly over the pastille at any desired distance. The reaction pastille may be compared with the control several times during the exposure to ascertain what fraction of the dose has been administered. To make a reading the reaction piece is taken to a poorly illuminated corner of the room (total darkness is preferable) and placed in the radiometer. The comparison is made with the aid of a shaded eight candle-power incandescent electric light.

Convenient illumination boxes are made for this purpose which consist of a box, painted black inside, open at the bottom, an eye-piece in the front wall, and containing a suitable source of illumination. Such

an apparatus permits only the reflected light from the pastille to reach the eye. The runner on the radiometer is moved up and down until an exact registration of color is obtained and then a reading is made by observing the relation of the notch in the reaction piece to the column of figures. A more detailed account of the use of pastilles will be found in the next chapter.

With a new instrument, fresh pastilles and an experienced eye, it is possible to detect and record very slight changes in color—less than ¼ H at skin distance. A weak point in the radiometer is that the celluloid band becomes soiled by contact with the fingers and scratched by the friction of the runner; and also, the numerals are gradually effaced by friction of the fingers. A more serious fault is the fact that the color of the celluloid band is not permanent; it assumes after a time, for an inch or two at the upper end, a greenish discoloration. This deterioration may occur in a few months or not for a year or two. When it does occur the instrument is no longer reliable.

FIG. 46.—Hampson radiometer.

The method of coloring the celluloid band is a secret and while American chemists can duplicate the index, it has thus far been impossible to get them to do so. During the past few years it has been impossible to obtain new instruments in good condition.

Hampson Radiometer (Fig. 46).—This instrument, designed by W. Hampson, of England, consists of two layers of stiff black cardboard, between which is a circular disc that may be made to revolve by the thumb. The dimensions are 3 x 3 inches. The edge of the disc contains a series of water-color tints, twenty-five in all, ranging from a

pale green to a deep orange. As the disc revolves the tints are seen through the upper of two windows. Under each tint there is a numeral which can be seen through the lower window. The upper window is divided by a narrow piece of black cardboard horizontally placed; the lower half contains the tinted edge of the revolving disc (color index); the upper half is for the half pastille that is to be compared with the index. The zero tint on the index is the color of a fresh, unexposed pastille. No. 25 is the color the pastille assumes after four successive epilating doses at skin distance, or one epilating dose at half distance. In other words Ha 6, at skin distance, represents the epilating dose. The above readings have been found to be too high for the average eye; Hampson, therefore, advises Ha 4 for the epilating dose at skin distance.

To use the instrument a fresh, unmounted, half pastille, after being enclosed in a piece of black paper, is placed on the skin directly under the anode. After or during the exposure the half pastille is placed in the upper window with its convex surface above. This operation should be conducted in a poorly illuminated portion of the room. The comparison is made with the aid of a shaded eight candle-power incandescent electric light. The reading is obtained by turning the disc until one of the tints matches the pastille and then the numeral in the lower window is noted. The pastilles should be handled with a pair of forceps.

Advantages and Disadvantages.—The Hampson radiometer is much cheaper than those of Holzknecht and Corbett, but, unfortunately, it is not as reliable. A comparison of several Hampson radiometers showed variations in the control tints. It is probable that the tints are accurate when they leave the factory and the color changes are due to the action of the elements. The actual comparison of the half pastille with the control is more difficult and less accurate with the Hampson than with the Holzknecht radiometer. In the first place it is impossible to place the half pastille in contact with the control—there is an embarrassing hiatus due to the horizontal strip of black cardboard. Then, the upper edge of the control is convex while the lower edge of the half pastille is straight. Finally, the pastille possesses a grain and a gloss that are lacking in the control. English pastilles, when they arrive in this country, are likely to be too dark to match the Hampson zero in a new instrument. Domestic pastilles match a new zero tint pretty accurately but are too light for older instruments.

Corbett Radiometer (Fig. 47).—This instrument designed by Dudley Corbett of England, is the result of an attempt to obtain a pastille radiometer possessing all the virtues and free of the limitations of the instruments already described. The radiometer is the direct result of experiments made with the Lovibond tintometer to create a standard Tint B. Corbett had noticed that the B Tint of the Sabouraud-Noiré radiometer varied in different instruments. This led him to test fresh pastilles with the tintometer in order to estimate the

colors and percentages contained therein. After deciding upon a standard color formula for Tint B, he studied, by means of a tintometer, the changes in colors and percentages thereof, in pastilles subjected to various doses of roentgen rays. In this manner he was able to create color formulæ for the various standard doses and fractions thereof.

The control scale consists of eight glass tablets; each tablet contains the requisite percentages of the proper colors for that particular dose. The eight tablets supply fractional dose controls from zero to Tint B. The optical instrument is a wooden tube, six inches long and one inch square, the inside of which is painted black. At the upper end there is a single opening for the eye. At the lower extremity there are two openings each of which is the size and shape of a pastille. Immediately under the apertures is a receptacle to accommodate the glass tablets. Two inches below this there is a platform which is covered with pure white standard paper (supplied with the instrument). The pastille is placed on the left side of the platform directly under the left lower aperture of the optical tube. Light from an eight candle-power incandescent electric bulb is allowed to shine on the pastille and white paper. The eye is placed close to the opening at the upper end of the tube;

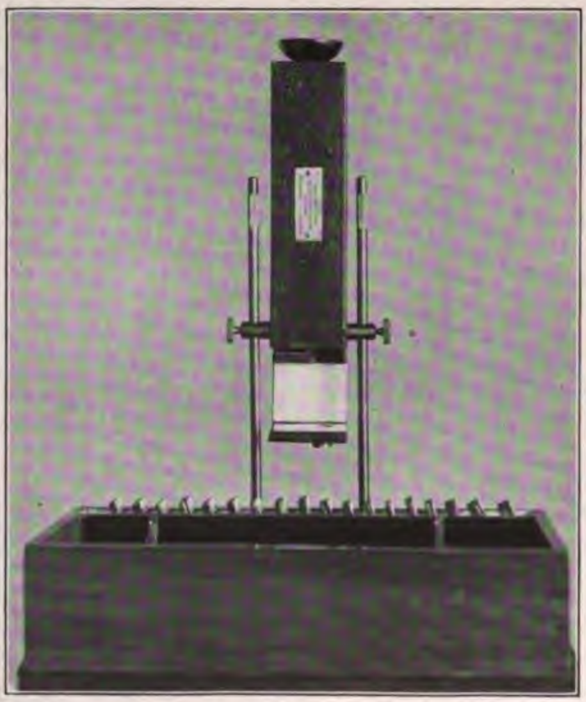

FIG. 47.—Corbett radiometer.

the reflected light from the pastille will reach the eye through the left aperture without passing through any colored medium. The reflected light from the white paper will reach the eye through the right aperture. Obviously, therefore, the left opening will be the color of the pastille, while the right opening will be white. Now the zero glass tablet is placed in the receptacle under the right aperture; the reflected light from the white paper now passes through the tinted glass and both openings register color. If the pastille has been exposed to an epilating dose at half distance, the Tint B tablet will match the pastille when employed as above described. With a little practice it is possible to obtain an astonishing degree of accuracy in matching tints, but there is a troublesome halation (bright halo at the periphery of the lower apertures), which is embarrassing until the eye becomes sufficiently practiced to disregard it.

There are two sets of glass tablets supplied with the instrument—one for use with artificial light and one for daylight. The tints supplied are:

Tint A
1/4 B
1/3 B
1/2 B
4/5 B
Tint B
1 1/5 B
2 B

These values are estimated at half distance; therefore, the tablet representing the epilating or erythema dose at skin distance is ¼ B. Care must be taken not to employ the daylight tablets when using artificial light and *vice versa*. In addition to tints already enumerated, there are three so-called neutral tints which are to be employed only with daylight—Tint A, ¼ B and ⅓ B. It was found that while these three standards would match the pastille in tint (daylight comparison) there was a confusing difference in brightness, the pastille being more brilliant than the control on account of white light being reflected from its surface. This brightness can be dulled by the interposition of one of the neutral tints which contain the requisite amount of red, yellow, and blue to absorb the white light. The three neutral standards are marked to correspond with the tints with which they are to be used.

The Corbett tints are accurately made and seem to be permanent. Hence we have a permanent, standard zero tint for fresh pastilles and the same for the epilating dose. While it is possible to match the pastilles with the controls with considerable accuracy, the author cannot admit that the comparison is as accurately, as easily, or as quickly made as is the case with the Holzknecht radiometer. The Corbett radiometer is the same price as the Holzknecht instrument, and it is a little less economical because it is necessary to use whole instead of half pastilles.

Cox Radiometer.- This consists of a more recent and improved type of Corbett radiometer. The difference is in a more convenient, but no more accurate method of comparison. The tinted glass tablets are

smaller and arranged at the periphery of a circular disc which is placed at the lower end of the optical tube. The pastille is placed in position and the disc rotated until the two apertures match in tint. A reading is then made by referring to the numerals on the disc. Eight standard tints are provided for use with artificial light and the tints represent half-distance estimation.

Ionto Radiometer.—Measurement by means of ionization was the first method employed to accurately estimate the intensity of roentgen and radium rays. It is employed by physicists and is exceedingly accurate, but no one has ever succeeded in perfecting a practical radiometer based on the principles of ionization. Szillard, of Paris, devised an ionization instrument for use by practical rœntgenologists which, however, never became popular. It consists of a small electrometer and a tiny static machine enclosed in a case. The electrometer is charged by a few turns of the influence machine and the degree of charge is indicated by a needle and a scale of figures. A small ionizing chamber, which is placed on the skin under the anode, is connected by one pole with the electrometer by a carefully insulated wire. The other pole is grounded. In order to avoid surface leakage the insulation must be perfect and the parts must be kept free of dust and moisture. The static machine also must be kept dry or it will fail to charge the electrometer. When radiation enters the ionizing chamber, ionization occurs, conductivity increases and the electrometer begins to discharge. The conductivity of the gases and hence the rate and amount of electrometer discharge depends upon the quantity of radiation reaching the ionizing chamber. With roentgen rays entering the chamber the electrometer needle begins to move from zero toward 10. The calibration of the scale corresponds with Kienböck units—ionto 10 equals 10 X—therefore when the needle reaches 10 an epilating dose has been administered. Inasmuch as ionization varies with penetration the calibration is correct for only one degree of penetration. But it is possible to utilize the calibration for different qualities by placing diaphragms of lead over the ionizing chamber, thus increasing or diminishing the amount of the latter to be influenced by the *x*-rays.

Shearer has the following to say relative to the possibility of utilizing ionization for estimation of roentgen-ray intensity in practical work: "All of us realize the need of better means of measurement in roentgen therapy. Otherwise the experience gained by painstaking labor and careful observation is not rendered available for others.

"Yet it must be admitted that the introduction of unusual methods, involving an experience *very* different from that possessed by the roentgenologist and where the conditions for reliable readings are hard to obtain, is quite likely to do harm and even to discredit measurements in general.

"The profession must not be misled by the use of scientific terms. Certainly ionization methods are invaluable in the research laboratory when they are used by those especially trained to recognize the condi-

ions which must be obtained for reliable results. But it may well be doubted whether the introduction of even well-designed apparatus of this kind for routine work would be conducive to better results, as it would be very hard to obtain the conditions needed while actually treating the patient.

"The ionization of a gas renders it able to conduct electricity when subjected to electrical tension or voltage. Every atom of the gas is made up of minute negative particles (electrons) and a total positive charge equal in amount to the negative. Certain processes will disrupt the atoms so that electrons and positive remainders will be separated. When such ionized gas is between two conductors and a considerable voltage is applied, the electrons move toward the positively charged plate and the positive remainders in the reverse direction. The latter are a few thousand times as heavy as the electrons and are slow moving. If left to itself an ionized gas rapidly regains its non-conducting state because of recombination of the positive and negative portions.

"If one is to measure the activity of the ionizing agent by the current between the plates (current = electron charge multiplied by the number of electrons reaching the wall of the chamber per second) we must remove the ions at high speed to prevent loss by recombination. To do this the voltage applied to the ionization chamber must transfer the maximum attainable or saturation current, *i. e.*, get the ions out quickly.

"Roentgen rays will ionize a gas and so long as the passing rays do not excite the peculiar secondary rays characteristic of that gas the amount of ionization is quite in proportion to the radiation *absorbed*. Roentgen rays striking the metal conductors will cause extra ionization in the chamber. This makes readings too large and by an amount difficult to estimate. Only in rare cases have all the rays been absorbed in the gas. The amount absorbed varies with the tube 'hardness' and there is no simple way to correct for the rays not absorbed.

"The conditions for reliable measurements may in part be stated as follows:

"1. Complete absorption of all roentgen radiation entering the chamber by the gas to be ionized. Or at least a constant fraction of the total.

"2. The characteristic secondary rays must not be excited to an extent interfering with the readings.

"3. The voltage applied to the ionization chamber must be large enough to secure saturation current.

"4. The electroscope, electrometer or galvanometer used and all connections must be well protected from radiation.

"5. The rays must not strike the walls of the chamber setting up corpuscular or secondary effects.

"It may well be doubted whether any simple and convenient device meeting even most of these conditions can be devised, and apparatus to do this work well is too complicated to meet the needs of routine

treatment. Such appliances in well-equipped research laboratories are invaluable and where the results are properly worked up and presented they will be of great help in therapeutic work. Done otherwise we will only encumber the pages of the literature with misleading results, and our offices with trinkets soon to be discarded at an expense that we can ill afford."

Comparison and Choice of Radiometers.—Each radiometer has its advantages and limitations. These may be enumerated as follows:

1. *Holzknecht Radiometer.*—Everything considered this is perhaps the most accurate of the pastille radiometers. One-half of a pastille is used for the control; the other half for the reaction piece. Therefore, if the colored celluloid band is in good condition the two half pastilles are bound to match at zero so that there can be no error here. For the same reason pastilles that are slightly discolored may be used. That is, there is no standard zero. The pastille makes its own zero. The disadvantages are that the color index is not permanent and the instrument is not obtainable at present.

2. *Hampson Radiometer.*—The chief difficulty with this radiometer is that the tints vary. Also it is impossible, in this country at least, to obtain pastilles that will match the zero tint. Domestic pastilles are too light and English pastilles are usually too dark; occasionally too light. Comparison is not as accurate as with the Holzknecht instrument.

3. *Corbett Radiometer.*—The advantage of this radiometer is in the permanent, accurate, standard tints. Domestic pastilles match the zero tint. English pastilles when received in this country are darker than the zero tint and cannot be used. The method of comparing the pastille with the control is a little more accurate than with the Hampson radiometer, but it is not as good as is the Holzknecht method. With the latter there is a possibility of error at the end of the dose but not at the beginning. With both the Hampson and Corbett radiometers there is a possibility of an error at the beginning and the termination of the treatment. The Corbett and Hampson radiometers possess the advantage of being easily obtained (at least this was true until recently).

4. *Kienböck Radiometer.*—The photographic method of measuring intensity has received the support of the physicists but it has never been as popular as the pastille method among practical roentgenologists. The main reasons for the popularity of the pastille method over the photographic method in this country are that before the war good pastille radiometers and good pastilles were easily obtained; good photographic radiometers were obtained with difficulty; and because many of the leading roentgen therapeutists favored pastilles in preference to photographic paper. About the only practical workers in this country to use the photographic method were men who were doing deep therapy.

The advantages and limitations of the photographic method were

outlined in the last chapter and need not be repeated here. The author has always preferred the pastille method of direct measurement and of the pastille radiometers he favored the one designed by Holzknecht. It is probable, however, that greater accuracy can be had by the photographic method in trained hands and if an American concern, under the direction of a physicist and a practical roentgenologist, would devise a standard photographic radiometer, such radiometer would undoubtedly supersede all other forms of direct measurement.

While it is true that direct estimation of intensity is no longer necessary in practical work, yet a reliable and practical radiometer is a great comfort. It would afford the beginner an opportunity to gain technical experience before treating patients; it could be employed as a check to the indirect or electrical method of intensity estimation; and, finally, it could be used to quickly standardize indirect technic. It is fortunate, indeed, that the indirect technic of today is so reliable for it is impossible at the present writing to obtain reliable radiometers, pastilles or photographic strips. This is no great handicap to the expert for he knows how to evolve a technic but it does make a difference to the beginner. At present the only way we have of standardizing a technic is by visible effects on the skin. This question of direct and indirect technic and standardization of such technic is discussed at greater length in Chapters IV and X.

With any type of radiometer the beginner should experiment a long time before attempting to treat patients.

TABLE OF UNITS OF QUANTITY.

Name.	Symbol.	Distance.	Epilating dose.
Holzknecht	H.	Half	5
Holzknecht	H.	Skin	1¼
Kienböck	X.	Skin	10
Sabouraud	S.	Half	Tint B
Hampson	Ha.	Skin	4
Corbett	Ct.	Half	Tint B
Corbett	Ct.	Skin	¼ B
Cox	Cx.	Half	B
Cox	Cx.	Skin	¼ B
Ionto	Io.	Skin	10

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3. Red then appears in increasing proportion, causing the tint to become deeper in tone.
4. The proportion of yellow remains constant throughout.
5. The experimental error for red is about 0.15.

Color formulæ for the various standard doses were established as follows:

0 B	Yellow 15	Blue 3.0
1/5 B	Yellow 15	Blue 0.5
2/5 B	Yellow 15	Red 0.25
3/5 B	Yellow 15	Red 0.7
4/5 B	Yellow 15	Red 1.0
B	Yellow 15	Red 1.45

Corbett's work has been of great value in establishing reliable colored standards for unexposed pastilles and for standard doses. The importance of this work is illustrated by the study of a number of Sabouraud B standards:

	Yellow.	Red.
1. An old standard, 1904–1905	15	2.0
2. One of similar date the employment of which caused dermatitis and permanent alopecia (this was returned to Sabouraud who pronounced it one-third too dark)	6	1.85
3. The same pastille after being corrected by Sabouraud returned as "Teinte B vraie"	8	1.2
4. About 1906–1907	9	2.0
5. About 1906–1907	8	1.45
6. 1908–1909	10	1.65
7. 1908 (Corbett standard)	15	1.50

Preservation.—It is advisable to have a permanent zero standard with which to compare new consignments of pastilles; otherwise there is no way of knowing if the new pastilles are of the proper color. For this purpose the author has employed the zero tint supplied with the Corbett radiometer. It is difficult to obtain pastilles from England or from the continent that will match this tint; they are of the proper color when first made but they dry out in transit or are kept in a dry place for too long a time while in the hands of the dealer.

As soon as the screen is made by the chemist it should be placed in a well ventilated humidor and when the pastilles are cut from the screen these, too, should be kept in a moist atmosphere while in the dealer's hands. While en route the pastilles can be placed in a small box containing a damp sponge; a few small holes being punched in the side of the box for purposes of ventilation.

The author has employed pastilles made by a chemist in this country. The screen is not made until ordered and reaches the laboratory in a day or two. It is then cut into pastilles by means of a sharp metal punch. In cutting pastilles it is important to have a very sharp punch which is driven through the screen with a single sharp blow of a heavy mallet. If not done in this manner the edge of the pastille will assume a reddish-yellow color. The same precaution is necessary when the pastilles are cut in half. As soon as received the screen, or the pastilles,

few minutes. It is obvious from the foregoing that heat from the tube in ordinary practical work is not an important factor.

Humidity.—The effect of moisture on the pastille is to retard alterations in color produced by roentgen rays. Furthermore, when a pastille has been colored by this agent a humid atmosphere tends to restore the normal color. Even at low and normal temperatures, if kept in a dry atmosphere, a perceptible change in pastille color occurs in a few months and, at times, in a few weeks. At higher temperatures (above 90° F.) tinctorial variations may occur in a few days. Alterations in color, due to lack of moisture are permanent.

Ultraviolet Rays.—In the literature it is stated that ultraviolet rays affect the pastille the same as do the *x*-rays with the exception that color change produced by ultraviolet rays involves only the surface of the pastille. The author has not been able to verify these statements. A pastille exposed for ten minutes to the rays from an Alpine lamp and a Kromayer lamp failed to show any appreciable change in color. Prolonged exposure to direct sunlight will alter the color and this alteration is permanent. It is probable that this effect is due to heat and dryness as the color change occurs throughout the pastille.

X-rays and Radium.—*X*-rays, gamma rays and beta rays all provoke the same color changes in the double cyanide of barium and platinum. This alteration, as observed by Howard Pirie, is not entirely permanent. If a pastille is exposed to *x*-rays until a distinct brown color is manifest, a partial recovery will follow exposure to daylight (not sunlight). A cool, moist atmosphere has the same effect. Even strong artificial light (possibly heat) such as that from an incandescent electric bulb will accelerate the recovery. The pastille never returns quite to its original color. At maximum recovery the pastille will register ¼ or ½ in the Holzknecht radiometer, depending upon the depth of color produced by the *x*-rays. After each exposure recovery is less until finally the pastille ceases to respond to any agent—it has lost its sensitiveness.

Chemistry of Color Change.—According to Levy the color change is due to the loss of water of crystalization. In other words, the above agents change the salt from the crystalline to the amorphous state. This explains why a used pastille is less sensitive than a fresh one and, also, why a pastille becomes less sensitive as color is added during an exposure.

To the eye a fresh pastille is greenish-yellow. Under the influence of the *x*-rays green is gradually lost until at a point approximating ½ epilating dose (half distance) the color is yellow. Then the color changes to orange and this becomes gradually deeper as the exposure is continued. Corbett, who has studied this color change by means of the Lovibond tintometer records the following:

1. The unexposed pastille is a mixture of yellow and blue.
2. The blue gradually disappears, until at a point just below the ½ epilating dose (half distance) yellow is the only color present.

Used pastilles that have "recovered" are not as accurate as are fresh pastilles. They no longer match the zero tint of the radiometer which makes it possible for a reading error to occur both at the beginning and at the end of a treatment. Such pastilles are a little less sensitive which permits another possible error. For work where great accuracy is required it is essential that the pastille match the zero tint Where such accuracy is not required, as in the treatment of epithelioma slightly colored pastilles may be employed.

Color Blindness.—The ability to detect slight color changes and to quickly and accurately match tints, varies considerably in different individuals. Some eyes are endowed with this ability while others must be trained or educated by practice. For this reason experience in pastille reading is necessary before the method is employed for practical purposes. For the same reason it is inadvisable to have the treatment begun by one individual and finished by another. That ordinary color blindness is an important factor in this work has not been proved. An individual might, for instance, say that the unexposed pastille is bluish yellow instead of greenish yellow. It is doubtful if this would make any difference provided that the eye possessed the ability to detect slight changes in tint. The unexposed pastille is composed of yellow and blue; under exposure to the x-rays the blue is lost and yellow is the only color—red then appears in increasing proportion. Color blindness may be in relation to any one or all of these colors, but even so it may be possible for the individual to detect slight tinctorial changes. Perhaps eyes exist that fail to match colors or to detect slight changes in tint. Such eyes, if the defect cannot be remedied by lenses or by education, are unsuitable for pastille reading. In this connection the author has never yet trained a person, male or female, who could not read pastilles accurately after an experience of several weeks.

The comparison of pastille doses with skin effects is discussed at greater length in the next chapter.

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CHAPTER IX.

ARITHMETICAL COMPUTATION OF *X*-RAY DOSAGE.

THE so-called indirect method of estimating roentgen dosage antedates all other schemes of measurement in practical work. The estimation is made by means of the spark gap, milliammeter, time and anode-skin distance. Before the advent of the interrupterless transformer and the Coolidge tube the method was exceedingly unreliable and gave way to the so-called direct technic (pastille and photographic radiometers). The chief requisite of indirect technic is ability to control voltage or if it means more to the reader, ability to establish certain technical "factors" or "constants" and to maintain them or vary them at will. Modern apparatus and instruments supply the demand to a degree that meets practical requirements.

In electrical measurement there are four factors which are of the greatest importance, namely, milliampèrage, voltage (spark gap), time and distance. These are the constants or factors that establish the technic. If we employ 2 milliampères of current, a 6-inch spark gap, a distance of 8 inches, and an exposure of three minutes, assuming that these factors remain constant throughout the exposure, a definite amount of radiation will reach the skin. It is obvious that every time that these factors are used the same quantity and quality of radiation will be produced. It is feasible, therefore, to establish a technic that is sufficiently accurate for practical purposes, that will duplicate results and that can be passed on from one operator to another. Furthermore, such technic has stood the test of time.

It is necessary or at least advisable for the operator to know how much radiation in terms of units is obtained with a given set of factors. This information can be ascertained in several ways.

Standardization by Effect on Skin.—Let us adhere to the constants already given—Ma. 2, Sp. G. 6 in., T. 3 min., D. 8 in. Utilize a split-pea sized area of skin on the flexor surface of the forearm of a female adolescent (preferably a blond) for the experiment. Establish all the constants except time. Make an exposure of one minute and wait two weeks for a possible erythema. If none appears, expose a similar area for two minutes, then for three minutes if necessary, and so on. Assume that the third area exposed (three minutes) develops a faint but definite erythema—Ma. 2, Sp. G. 6, T. 3 min., D. 8 in., will be the erythema dose and this particular technic is standardized. Any set of constants may be employed, but with every set used it is necessary to ascertain the erythema dose as above outlined. After the erythema dose has been established, it is necessary only to split the time to determine fractions thereof. The reason for selecting a young fair skin

and a flexor surface is because such skin is more sensitive than dark skin on the extensor surface of older individuals. Obviously, it is preferable, for the sake of safety, to standardize the erythema dose on sensitive normal skin rather than on comparatively insensitive skin. The erythema dose for the average skin is often spoken of as the skin unit (H1 skin distance; H 4; 8 X). To standardize the epilating dose similar experiments may be carried out on minute areas of the scalp. Because of medico-legal possibilities it is advisable to apply these experiments to the person of the operator. Because of the difference in susceptibility between human skin and the skin of lower animals, the latter will not answer for the purpose of standardizing a technic for human skin.

The objections to standardizing a technic by visible skin effects are perhaps numerous, but the chief ones are the length of time required and the fact that the skin of different persons and the skin in different parts of the same person, will react differently to the same dose. The skin of the flexor surface of the forearm, the axillæ, the anterior neck and the face will, in some young persons, react to a half skin unit, while it may require a full skin unit to affect a reaction of the skin in other locations. It is preferable, therefore, to make a number of experiments in different parts of different persons and ascertain the dose that will effect a reaction under different conditions. As will be seen later, the erythema dose has been standardized as 1 Holzknecht unit with the pastille on the skin. This amount of x-rays will effect an erythema on sensitive parts but not on insensitive parts such as the scalp. It is necessary to have some standard and H1 to H1¼ skin distance is the accepted standard for the erythema dose. If the novice attempts to standardize a technic by visible skin effects he must realize that a dose that will produce an erythema on a sensitive part will not effect the same result on a less sensitive part of the same individual and *vice versa*. If one is attempting to ascertain by skin effects, with a definite set of constants, the standard H1 at skin distance, it is preferable to select the skin on the flexor surface of the forearm of a male adult brunette.

Radiometric Standardization.—This consists of utilizing pastille or photographic paper to determine the time required for the erythema dose with a given set of constants. The method has the advantage of requiring only a few minutes, but it demands considerable experience with at least one reliable type of radiometer.

Physical Laws.—Before proceeding further it is necessary for the reader to understand and memorize certain physical laws:

1. Intensity varies directly as the square of the voltage (photographic).
2. Intensity varies directly as the voltage (pastille).
3. Intensity varies directly as the milliampèrage.
4. Quantity varies directly as the time.
5. Intensity varies inversely as the square of the distance.

All methods of measurement agree with these laws excepting that relating to voltage (spark gap), where photographic and pastille methods give contrary results. Visible skin effects, so far as can be ascertained by such methods, agree with pastille measurement; therefore for superficial therapeutic work we accept the second law.

To explain these laws in a different manner: (1) Doubling the spark gap, doubles the dose. (2) Doubling the milliampèrage, doubles the dose. (3) Doubling the time, doubles the dose. (4) Doubling the distance gives one-quarter of the dose.

It should be clearly understood that these laws pertain only to *superficial* therapeutic work with *unfiltered rays*. It is also of the utmost importance to realize that "distance" means from the anode to the skin; not from the glass wall of the roentgen tube to the skin.

Use of Equations.—It is preferable that the roentgenologist become accustomed to the use of equations, because mathematical formulæ allow of visualization and arithmetical computation. The following formula is for unfiltered *x*-rays in superficial therapy:

$$\frac{\text{Current} \times \text{voltage} \times \text{time}}{\text{Distance} \times \text{distance}} = \text{intensity at the surface}$$

or, expressed in arbitrary figures:

$$\frac{20 \times 5 \times 4}{20 \times 20} = \frac{400}{400} = 1$$

Shearer, by photographic measurement (comparison of densities on photographic plates) has shown that doubling the voltage increases the intensity by four. That is to say, if voltage is doubled, four times more radiation will reach the skin. Shearer's formula is as follows:

$$\frac{\text{Current} \times \text{voltage} \times \text{voltage} \times \text{time}}{\text{Distance} \times \text{distance}}$$

The following numerals, selected for mathematical convenience, may be used to replace the nouns in the formula:

$$\frac{20 \times 5 \times 5 \times 4}{20 \times 20} = \frac{2000}{400} = 5$$

If voltage is doubled intensity will be increased four times. That is, four times as much radiation will reach the plate as shown by the next formula:

$$\frac{20 \times 10 \times 10 \times 4}{20 \times 20} = \frac{8000}{400} = 20$$

The author's associate, John Remer, in collaboration with W. D. Witherbee, of the Rockefeller Institute, by carefully conducted pastille measurement demonstrated that, by this method, doubling the spark gap instead of increasing intensity four times, as in photographic measurement, simply doubles the dose. Furthermore, they showed as will be seen later, that pastille measurement apparently corresponds

with the effect on the skin. If, therefore, pastille measurement is to be accepted as a basis for therapeutic technic the following formula must be used:

$$\frac{\text{Current} \times \text{voltage} \times \text{time}}{\text{Distance} \times \text{distance}}$$

Or, expressed in the figures previously employed:

$$\frac{20 \times 5 \times 4}{20 \times 20} = \frac{400}{400} = 1$$

Now if voltage is doubled intensity is also doubled thus:

$$\frac{20 \times 10 \times 4}{20 \times 20} = \frac{800}{400} = 2$$

Pastille readings are recorded, as a rule, in Holzknecht units, while photographic measurement is usually given in Kienböck units. To change a Holzknecht to Kienböck reading it is necessary to double the former. The explanation is that, with the pastille, doubling voltage doubles the dose while, photographically, doubling voltage increases the dose by four.

To test the accuracy of pastille measurement, to determine the effect of varying the factors, and to obtain the ratio between pastille measurement and skin erythema, the following experiments were conducted by Remer and Witherbee:

	Ma.	Sp. G.	Distance.	Time.	Skin.	Pastille reading. One-half distance.
1	3	3	8	2	½ H.	2 H.
2	3	6	8	2	1 H.	4 H.
3	3	9	8	2	1½ H.	6 H.
4	3	6	16	2	¼ H.	1 H.
5	3	6	16	4	½ H.	2 H.
6	6	3	8	2	1 H.	4 H.

By comparing experiments Nos. 4 and 2 it is obvious that intensity varies inversely as the square of the distance. Comparison of Nos. 2 and 1 reveals that doubling voltage also doubles intensity. Nos. 1 and 6 show that the pastille reading is doubled when milliampérage is doubled.

The next experiment determines the ratio between pastille readings and the effect on the skin. Four areas of a man's back were treated with the following factors:

1. $\frac{3 \times 3 \times 5}{8 \times 8} = 1\frac{1}{4}$ skin $=$ 5 H.

2. $\frac{3 \times 6 \times 2\frac{1}{2}}{8 \times 8} = 1\frac{1}{4}$ skin $=$ 5 H.

3. $\frac{3 \times 4\frac{1}{2} \times 3\frac{1}{2}}{8 \times 8} = 1\frac{1}{4}$ skin $=$ 5 H.

4. $\frac{3 \times 9 \times 1\frac{2}{3}}{8 \times 8} = 1\frac{1}{4}$ skin $=$ 5 H.

Areas 1 and 3 are controls. In areas 2 and 4 the spark gap was doubled and the time cut in half. The pastille registers the same dose in each instance and the intensity of erythema is apparently the same in each area as depicted by the photograph of the patient (Fig. 48) taken ten days after the exposure.

From the foregoing it is obvious that with either the pastille or photographic method a standard formula possessing a definite value can be established. From this formula it is possible to compute the dose for any set of factors.

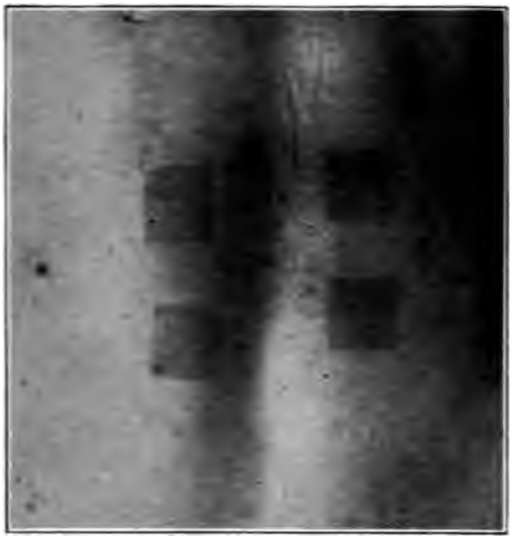

FIG. 48.—Four areas of *x*-ray erythema all of which are apparently of the same degree. Explanation will be found in the text.

The following formula has been established by Remer and Witherbee as representing (pastille measurement) the so-called skin unit (H1 skin distance; H4, half distance; 8X):

$$\frac{3 \times 3 \times 4}{8 \times 8} = \frac{36}{64} = 1 \text{ skin unit.}$$

The arithmetical rules for this work are:

1. For determination of intensity or quantity divide the product of any formula by the product of the standard formula.

2. For determination of time divide the product of the standard formula by that of the new formula.

In order to demonstrate arithmetical computation the following examples are given: If time is increased by one minute what will be the result?

$$\frac{3 \times 3 \times 5}{8 \times 8} = \frac{45}{64}$$

The product of this formula is divided by that of the standard formula thus:

$$\frac{45}{64} \times \frac{64}{36} = 1\tfrac{1}{4} \text{ skin units} = \text{H } 5.$$

What will be the dose if the spark gap is doubled?

$$\frac{3 \times 6 \times 4}{8 \times 8} = \frac{72}{64} \times \frac{64}{36} = 2 \text{ skin units} = \text{H } 8.$$

Suppose the distance is changed from 8 to 12 inches:

$$\frac{3 \times 3 \times 4}{12 \times 12} = \frac{36}{144} \times \frac{64}{36} = 0.44 \text{ (a little less than } \tfrac{1}{2} \text{ skin unit).}$$

With 2 milliampères, a 6-inch gap and an exposure of three minutes, what distance would be required to obtain 1 skin unit?

$$\frac{2 \times 6 \times 3}{X^2} = 1 \text{ skin unit} = \frac{36}{64}$$

Therefore

$$\frac{36}{X^2} = \frac{36}{64}$$

$$X^2 = 64$$

$$X = 8 \text{ inches distance.}$$

If ¼ skin unit were desired, using the same factors, what distance would be required?

$$\frac{2 \times 6 \times 3}{X^2} = \tfrac{1}{4} \times \frac{36}{64} = \frac{9}{64}$$

Therefore

$$\frac{36}{X^2} = \frac{9}{64}$$

$$X^2 = \frac{36 \times 64}{9} = 256$$

$$X = 16 \text{ inches.}$$

If the milliampèrage is changed from 3 to 2 the result will be:

$$\frac{2 \times 3 \times 4}{8 \times 8} = \frac{24}{64} \times \frac{64}{36} = \tfrac{2}{3} \text{ skin unit.}$$

If the operator finds it more convenient to employ 2 milliampères, a 6-inch gap, and a distance of 8 inches, how much time will be required for the administration of 1 skin unit?

$$\frac{2 \times 6 \times T}{8 \times 8} = 1 \text{ skin unit} = \frac{36}{64}$$

hence,

$$T = \frac{36}{64} \times \frac{64}{12} = 3 \text{ minutes.}$$

From such a formula it is possible to compute a dose chart giving the time factor for a dose of any size (Chart 12 p. 144).

Pastille Readings and Arithmetical Computation.—Mathematical estimation, based on pastille reading, has been worked out only for the so-called skin unit (H1 S.D.) and for the maximum epilating dose (H1¼ S.D.). It is not advisable to employ this method for larger doses without clearly understanding that such doses will not correspond with pastille readings on the Holzknecht radiometer. The following is offered as an example: The formula

$$\frac{3 \times 3 \times 5}{8 \times 8}$$

will provide an erythema dose (H1¼ S.D.) as proved by pastille reading and by the effect on the skin. Now, if the time is doubled, other factors remaining unchanged, it can be assumed that double the amount of radiation has reached the skin and in all probability the biological result is twice as great. The pastille, however, does not assume twice as much color or at least it will not register H2½ on the Holzknecht radiometer. In other words, if with given factors, it requires five minutes to color a pastille from zero to 1 on the Holzknecht instrument it will require more than ten minutes to have the pastille register 2 on the same scale. In expressing dosage, therefore, it is advisable to explain exactly what has been done. H2 at skin distance signifies that a single pastille has been colored from zero to 2. This is a larger quantity than two skin units.

The reason for this difference is because the pastille, as it assumes color, becomes less sensitive. It obeys the laws (stated supra) fairly well up to H1¼ S.D., after which it fails to follow the time law.

Milliampère-minutes.—Not infrequently roentgenologists find it convenient to combine, by multiplication, the tube current in milliampères and the time in minutes and express dosage in terms of milliampère-minutes. But it must be clearly understood that the number of milliampère-minutes allowable varies with the spark gap and the distance. The standard formula used in this chapter—

$$\frac{3 \times 3 \times 4}{8 \times 8}$$

—expressed in milliampère-minutes would read: Sp. G. 3, D. 8, Ma-Min. 12. The milliampère-minutes may be split in any manner so long as the product is the same: 1 Ma. for twelve minutes; 12 ma. for one minute; 6 ma. for two minutes, etc.

According to the work of Pfahler and others, on a 5-inch gap the number of milliampère-minutes required for a full erythema dose at a distance of 20 inches, allowing no factor of safety, will be about 60, without filtration. Expressed differently, 5 Ma., 5-inch Sp. G., 20 inches skin target distance and twelve minutes will almost certainly provoke an erythema. If this formula is divided by the standard pastille formula the result is as follows:

$$\frac{5 \times 5 \times 12}{20 \times 20} = \frac{300}{400} \times \frac{64}{36} = 1\tfrac{1}{3} \text{ skin} = 5\tfrac{1}{3} \text{ H.} = 10\tfrac{2}{3} \text{ X.}$$

The maximum epilating dose for scalp hair, unfiltered, is H1¼ at skin distance; H1 S.D., will usually suffice. The erythema dose for the skin may range from H¾ S.D. to nearly H2 S.D., depending upon age, location and other conditions, but it is usually regarded as being about H1 S.D. or H1¼ S.D. The above formula was published as the limit of safety in unfiltered diagnostic work. It would seem preferable to limit the exposure to H¾ (about 30 milliampère-minutes with the above formula) providing one does not desire an erythema. In filtered work and in unfiltered work where a first degree reaction is of no consequence, larger amounts may be administered.

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CHAPTER X.

PRACTICAL ROENTGEN-RAY TECHNIC (UNFILTERED).

TECHNIC FOR THE BEGINNER.

It is assumed that the beginner has studied the preceding chapters, that he has installed reliable, modern apparatus and instruments, and that he is now ready to establish a working technic for practical therapeutic purposes. We have to consider, from a purely practical standpoint, three possible technics, namely, indirect, direct and a combination of the two.

INDIRECT TECHNIC.

In a preceding chapter we reviewed the arithmetical determination of dosage. We saw that this arithmetical method was based upon radiometric standardization and skin effects together with certain well-established laws relative to the following essential technical factors: milliampèrage, voltage, time and distance. It is obvious that the first step in the so-called indirect technic is to decide upon the factors for routine work. These may be anything the operator desires. But it is advisable to employ factors that are easily and quickly obtained and that will supply the desired dose in a reasonable time—neither too slowly nor too rapidly. Very slow and very rapid work is more confusing and less accurate than is a sensible point between the extremes. A technic that will administer an erythema or epilating dose in three or four minutes is satisfactory for routine work.

In routine work the author has used the following factors for several years; they have been found reliable and convenient: milliampères, 2; spark gap, 6; time, three minutes; distance, 8 inches. This formula will give 1 skin unit and may be expressed mathematically, thus:

$$\frac{2 \times 6 \times 3}{8 \times 8} = 1 \text{ skin unit} = 4 \text{ H.}$$

From this formula it is possible to compile a chart in which the standard doses are obtained by changes in time, all other factors remaining constant. Chart 12 supplies this information.

To obtain milliampèrage and voltage proceed as follows: Place the main control (rheostat or autotransformer) on the first button (resistance in circuit). Do the same with the filament control. Set the spark gap at 6 inches. Close the filament switch and be certain that the filament is heated. Close the *x*-ray switch. Current will now pass through the tube and *x*-rays will be produced. The milliammeter will register perhaps 1 ma. or less. Sparks will probably not jump across the spark gap. Increase the filament current until the milliammeter (not the ammeter in the filament circuit) records 2 Ma. Now, during the operation of the tube, advance the handle on the main control from button to button until sparks jump across the gap. The

milliammeter will now register over 2 Ma., possibly 2½ Ma. Reduce the filament current until the milliammeter reads 2. If sparking across the gap is too vigorous move the main control back one button. In other words continue to adjust the two controls until 2 Ma. and a 6-inch gap are obtained. After these two factors have been established they must be maintained throughout the exposure. With the main control in the same position one factor will probably not change unless the other does. If milliampèrage increases the spark gap will become shorter and *vice versa*. Therefore all that is necessary is to hold milliampèrage by adjustment of the filament control. It is, however, advisable to also watch the spark gap and if it increases or decreases without apparent change in milliampèrage, the correction can be made by a slight readjustment of the two controls without interrupting the exposure.

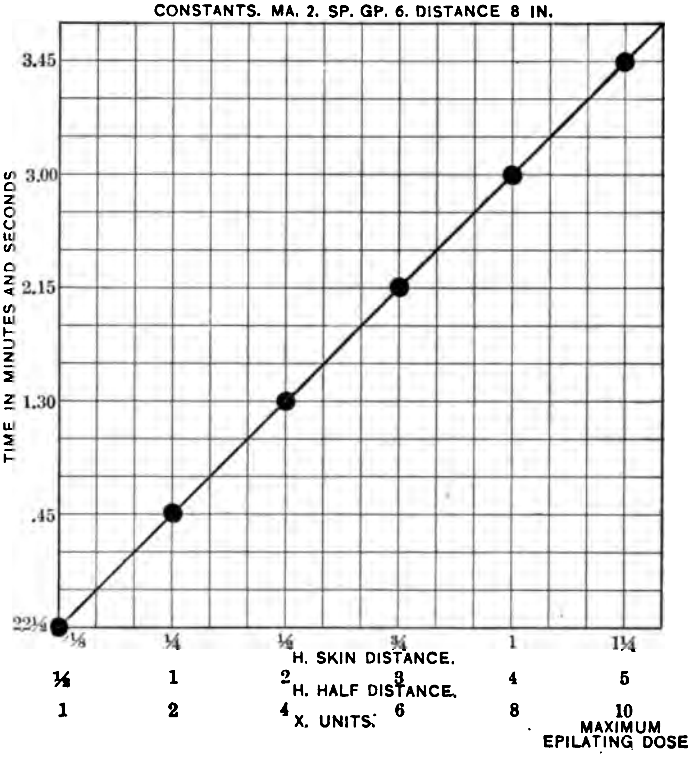

CHART 12.—Dose chart for unfiltered superficial therapy.

Points on either control or on the filament ammeter must not be considered as "constants" as they will vary with conditions—atmospheric variations, changes in line voltage, condition of brushes, etc. The main thing thus far is to appreciate that every time a treatment is to be given the controls are to be adjusted so as to give Ma. 2, Sp. G. 6 and then these two factors are to be maintained during the

entire exposure. To avoid ionization of the air in the room with consequent changes in conductivity suitable ventilation should be provided.

The question naturally arises as to whether or not a given indirect technic with one outfit will give the same result with another apparatus of the same type but different manufacture. The answer is that there is surprisingly little difference between the various makes of modern apparatus in this respect. The relation between milliampèrage and voltage is practically the same in all reliable interrupterless transformers. While the break-over spark is not quite the same in all transformers yet it is doubtful if the variation is sufficiently great to make any practical difference. Observers vary somewhat in their estimation of what constitutes a spark gap. Some are satisfied with an effluve at the terminals while others demand a constant stream of sparks. On account of possible differences in the output of apparatus of various makes coupled with confusion relative to what constitutes a spark gap and the possibility of the milliammeter giving a faulty reading, the novice is encouraged to test the technic by the pastille or photographic method or by skin effects, preferably the last, before administering the *x*-rays therapeutically.

In this connection the author has tried the indirect technic as outlined in this chapter on several different interrupterless transformers from the same manufacturer and on similar apparatus from several other manufacturers. There was not enough difference to be detected by pastille measurement.

Assuming that the operator has tested his apparatus it may be stated that a standardized indirect technic is reliable on any interrupterless transformer and that such technic may be handed from one operator to another. With such technical standardization it becomes possible for a patient to travel from city to city and to receive the same dose in the same manner in each place. In order to obviate confusion as to just what is meant by standard modern apparatus the following requisites are given: (1) Closed magnetic circuit interrupterless transformer giving a rectified current, with rheostat or autotransformer control (usually the former). (2) Coolidge tube with filament circuit from a storage battery or step-down transformer (usually the latter) and a quick acting and finely graded control. In the case of a step-down transformer the control usually consists of a choke coil. (3) a suitable conducting system for the high-tension current and a correctly reading milliammeter.

Time.—The time factor should be judged by means of a stop-watch. If the exposure is interrupted for any reason—refractory patient; trouble with apparatus—the number of seconds already utilized must be accurately determined and recorded.

Distance.—An error in distance will have a profound effect on dosage. It must be borne in mind constantly that intensity varies inversely as the square of the distance and that, therefore, if the distance should be decreased one-half the dose would be increased four times. By the term "distance" is meant the number of inches between the target and the skin. To establish this factor it is first necessary to measure the

circumference of the tube from which the diameter and radius may be estimated. If, for instance, the circumference is 22 inches the diameter will be 7 inches (7.0088 in.) and the radius 3½ inches. To obtain a skin target distance of 8 inches cut a piece of wood to exactly 4½ inches and adjust the tube so that one end of the measuring stick touches the wall of the tube while the other extremity touches the lesion. Inasmuch as the circumference of different tubes varies it is advisable for the operator to measure each tube. If the circumference should be 21½ instead of 22 inches, the radius would be 3.4 instead of 3.5 inches and, to be exact, the measuring stick should be 4.6 instead of 4.5 inches.

In establishing distance it is important that the measuring stick touch the glass wall of the tube at the equator directly under the anode and also the skin directly in the center of the lesion. It seems superfluous to add that the distance must be accurately maintained during the entire exposure. But it is carelessness in this regard that causes many of the errors of roentgen therapy. It often happens that the part moves a little closer, or a little farther away, or a little to one side, without attracting the attention of the operator. The author on one occasion found that the tube holder had slid down the stand so that the skin-target distance was reduced from 8 to 6 inches. One must be cognizant of these possibilities and guard against them. The tube and tube holder should be firmly fixed. The patient must understand the necessity of maintaining position and even with the patient's coöperation the operator or the assistant should watch the part for motion. To insure against change of position some operators employ a small rubber suction cup which is fastened to the wall of the tube from which is suspended a string 8 inches long at the lower end of which is attached a small ball made of soft wood and which comes in contact with the skin. Another device consists of a tube-stand equipped with adjustable pegs of soft wood. Finally, the part to be treated can be securely fixed by the use of sandbags, roller bandages, etc.

DIRECT TECHNIC.

As was explained in a previous chapter, the so-called direct method consists of estimating the quantity of rays reaching the skin by means of a radiometer—pastille or photographic. It means that every dose of *x*-rays administered is measured either by means of a pastille or a photographic strip. The method has its advantages: It is not necessary to maintain a constant distance. It makes no difference if the part moves nearer or farther away excepting that the time required to color the pastille will be modified accordingly. Any combination of milliampèrage and voltage is allowable. Fluctuation in voltage or current will, like change in distance, simply modify the length of time required to obtain the desired alteration in the color of the pastille. Mathematical errors, mechanical errors, etc., may be disregarded. The point to emphasize is that one depends entirely upon the pastille or photographic strip and regardless of the factors employed the

exposure is not terminated until the dose is registered by the radiometer. It is often difficult for the student to appreciate the fact that with pastille measurement, insofar as concerns erythema, the effect of H1¼ S.D. will be the same regardless of the quality.

Lateral motion must be avoided because it is necessary that the pastille be placed in the center of the lesion and directly under the target. Care must be taken that no part of the lesion is closer to the tube than is the pastille.

It is inadvisable to attempt direct measurement until the eye has been trained to quickly detect slight tinctorial changes. To avoid giving a larger dose than was intended it is necessary to examine the pastille two or three times during the exposure. Inasmuch as color is lost when a pastille is exposed to strong artificial light, these comparisons must be made quickly—hardly more than a glance. This is especially true of the deeper tints. At H2 a pastille will lose color perceptibly in one or two minutes; at H1 the loss of color is very much slower. For details regarding the use of photographic strips see Chapter VI and for further details relative to pastilles see Chapters VII and VIII.

The disadvantages of the direct method are: the difficulty of obtaining reliable radiometers, pastilles and photographic strips; the time required to train the eye to detect slight changes in tint and photographic half-tones; the fact that most radiometers are not permanent, many of them are difficult to read and some are unreliable even when new; necessity for care in preserving pastilles and strips; necessity of developing the strips.

Enumeration of practical requirements of direct method:

1. Pastilles and photographic strips must be in perfect condition and should match the zero tint of the radiometer.

2. Enclose the pastille or strip in a black envelope and attach the envelope to the center of the lesion directly under the target with court plaster or a very small piece of zinc plaster. If not securely fastened the envelope and contents may become displaced during the exposure. Make certain that no part of the lesion is closer to the skin than is the pastille.

3. Avoid lateral motion as the pastille may be carried out of the field of the direct beam so that some portion of the lesion might receive a larger dose than is recorded by the pastille or strip.

4. Unless one knows about how long a time is to be required for the exposure it is necessary to compare the pastille with the standard scale several times during the exposure to insure against overdosing. To prevent loss of color these comparisons should not endure more than ten or fifteen seconds each. If photographic paper is used, two or three strips should be employed—two are to be developed at different stages of the exposure and one left to record the full dose.

5. Milliampèrage, voltage and distance can be anything the operator desires. Fluctuations in current, in voltage, and changes in distance, while not desirable, can be ignored so far as concerns safety. One depends entirely and solely upon the pastille reading.

Half Distance and Skin Distance.—These two terms have caused a great deal of confusion. All pastille radiometers, with the exception of the ones devised by Corbett and Hampson were originally used with the pastille placed exactly half way between the anode and the skin. This was done because at half distance the pastille acquires more color than at skin distance and it was thought that the deeper tints were more readily compared than were the paler tints. Hampson was the first to call attention to the full-distance position. With the pastille on the skin it acquires 4 times less color than when placed at half distance and to obtain a reading in H units (which are estimated at one-half distance) the reading must be multiplied by four. With the pastille on the skin the dose is read in skin units or H units at skin distance and *regardless of the distance between the target and the skin (pastille) the reading must be multiplied by four for conversion into H units.* To make this perfectly clear the reader must first bear in mind the law: intensity varies inversely as the square of the distance. Now, with the pastille on the skin and a skin-target distance of 8 inches, assume the dose to be H1. A pastille placed at half distance (4 inches from target and 4 inches from skin) will register H4. This explanation holds for any skin-target distance.

Full distance has many advantages over half distance. Contrary to what has been taught in the past, the deeper orange tints are compared with greater difficulty and less accuracy than are the paler tints. The deeper colors fade more rapidly than do the lighter tints when exposed to moisture and light. It is exceedingly difficult to maintain the half distance position. Not only are mechanical difficulties encountered, but the slightest movement of the part under treatment will give rise to an error in dosage. At half distance it is not possible to place the tube close to the skin because the pastille will be too near the glass wall of the tube, and may be affected by the heat of the target.

COMBINED TECHNIC.

This consists of utilizing the indirect method and employing either a pastille or a photographic strip as a control. Previous to the advent of modern apparatus and instruments it was the best technic because it combines the advantages of both methods and eliminates, as far as is practicable, all possibility of error. The disadvantages and inaccuracies of one are compensated to a large extent by the advantages and accuracies of the other.

It is not possible to measure less than H ¼ S.D. (H1) with a pastille, so for fractional doses of less than this amount it is necessary to depend upon the indirect technic, the photographic method, or a combination of the two.

POSSIBLE SOURCES OF ERROR.

Indirect Technic.—1. Unsteady current. This may be due to unavoidable voltage fluctuations in the main; the capacity of the main may be too small; it may be influenced by alternate light and heavy

loads in other parts of the building; dirty or worn brushes and short circuits; poor connections in the filament circuit or an unsteady filament supply.

2. Inaccurate milliammeter and kilovoltmeter. Differences in estimating spark-gap lengths.
3. Possible variations in the break-over spark in apparatus of different makes.
4. Arithmetical errors.
5. Leakage in the secondary circuit.
6. Failure to obtain and maintain the 4 important factors—milliampèrage, voltage, time and distance.
7. Assumption that H2 S.D. and two epilating or erythema doses are the same (see page 141).

Direct Technic.—1. Inaccurate radiometer.

2. Inaccurate pastilles.
3. Very long treatments (one-half hour or more) in excessively moist climates.
4. Exposure of the pastilles to daylight or artificial light during the exposure. Exposure for too long a time to artificial light during the reading of the pastille.
5. Failure to place the pastille in the center of the part to be treated and directly under the anode; or in a depression so that some part of the lesion is closer to the tube than is the pastille; or failure to fix the pastille or photographic strip to the lesion. Lateral movement of the lesion.
6. Inability to detect slight changes in tint or shades.
7. Overdosing due to failure to read the pastille or strip during the exposure; or failure to employ the check or control offered by the indirect technic.
8. Poor judgment. The proper dose must be selected for the individual case.
9. Faulty photographic technic, or use of photographic paper that has not been standardized or paper that is too old.

Technic Advised by the Author.—It is a pleasure to say that direct technic is no longer necessary. It is assumed that the reader will use a rectified high-tension current from an interrupterless transformer of standard type with closed magnetic circuit, to operate an ordinary Coolidge tube. Under these conditions the novice, in unfiltered work, is urged to be guided entirely by Chart 12 (Chapter IX). The technic as represented by this chart is accurate and the operator need have no fear. A copy of the chart should be pasted on the wall close to the switches and controls. The doses given in the chart are standard amounts and they have been tested by many men over a period of several years. It is important to realize that the figures represent maximum amounts. That is, H1¼ S.D. is exactly H1¼ S.D. and must not be exceeded by a fraction.

More experienced operators may desire to vary the technic. They may, for various reasons, wish to use more current, or longer or shorter wave lengths. If so they may be guided by the chapter dealing with arithmetical computation (Chapter IX).

The Margin of Safety.—In the chapter on idiosyncrasy information will be found relative to the sensitiveness of the skin of various parts of the body, in individuals of various ages, in blonds and brunettes, of skin that has been modified through the agency of disease, by the action of irritating and stimulating local applications, etc. These factors all have an important bearing on the so-called margin of safety. But ignoring these for the moment and considering only the question of technic, is the latitude of safety sufficient to compensate the possible error in technic? All that is required in practical work is a reasonable degree of accuracy. Slight errors, even with the best technic in the most experienced hands, cannot be avoided with the present practical methods of producing, controlling and measuring the *x*-rays. Fortunately, the margin of safety offers a latitude sufficiently great to compensate unavoidable inaccuracies. The question can be discussed arithmetically. The most accurate work is required in depilating scalp hair for the cure of ringworm and favus of the scalp. It requires H1 S.D. to effect a defluvium, but H1¼ S.D., may be applied with perfect safety. Anything over this amount may provoke an erythema and lead to permanent alopecia. We have, then, a latitude of at least ¼ skin unit for the scalp epilating dose. An experienced operator, with modern apparatus, finds no difficulty in confining the possible error to this amount. The margin of safety is even greater when dealing with the skin. One skin unit is likely to cause an erythema, but it requires at least double this dose to effect a reaction of the second degree and 2½ to 3 skin units to cause a third degree reaction. Here, indeed, is a big margin of safety insofar as concerns second and third degree reactions.

Training.—The beginner should not be in a hurry to treat patients. After the installation of modern apparatus and instruments one should practice manipulating the controls and obtaining the "constants." After becoming acquainted with the apparatus and technic it is a good idea to expose a photographic plate to the doses shown in Chart 12. By suitable protection with black paper and lead it is possible to make all the exposures on one plate in such manner, that after development there will be a series of graded half-tones or shadows representing the various doses. Finally very small areas (split-pea-sized) of normal human skin should be exposed to the various amounts from H¼ S.D. to H1¼ S.D. After acquiring confidence it is advisable to cautiously apply fractional doses to disease before attempting intensive treatment. The first attempts at intensive or hyperintensive treatment should be in cases of epithelioma.

Records.—It is important to preserve a record of every case. Every roentgenologist will compile a history card and index system best suited to his individual requirements. Instead of a card the author prefers a sheet of fairly heavy paper folded so as to make four pages. The dimensions, after folding, are 8½ x 11 inches. This is kept in a manilla envelope and filed in an ordinary letter file. The first page deals with the history of the patient while the three remaining pages record the treatments and observations. The first and second pages

of this history chart are herewith appended. The third and fourth pages are identical with the second. The histories are indexed by the name of the patient and, in addition, it is advisable to have a cross-index by diseases, using for this purpose a 3 x 5 card.

First Page.

Name: Mr. John Smith.

Address: 402 Madison Avenue, N. Y. City.

Referred by: Dr. R. R. Jones, 212 West 144th St., N. Y. City.

Date: September 7, 1914. *Age:* 56. *Mar.:* *Sing.:* *Wid.:*

Occupation: Broker. *Nationality:* U. S. A. *Blond:* *Brunette:*

Duration of present eruption: 6 years. *Of disease:* 6 years.

Size: Dime. *Photograph No.:* 806.

Location—Distribution: Center of left cheek.

Diagnosis: Epithelioma (Basal cell).

Family History: Negative.

Past history: Very slow evolution. Has grown more rapidly during past six months. Lesion has never been treated excepting with mild ointments.

Laboratory findings: Small piece of lesion examined in skin department of Vanderbilt Clinic shows anatomical structure of basal-cell epithelioma. Biopsy No. 1, 220.

Present Condition: Lesion consists of a hard mass, elevated ¼ inch. Margin is composed of semi-translucent nodules. Center is crusted. Crust, when removed, shows underlying necrosis.

Second Page.

Date.	Formula.	Filter.	Areas.	Dose.	Remarks.
Sept. 7, 1914	$\frac{2 \times 7 \times 8}{8 \times 8}$	None	Lesion and surrounding skin	H2 S.D.	Curettage under cocaine; skin for ¼ inch outside of lesion treated.
Sept. 25, 1914	....	....	....	....	Mild second degree reaction; wet dressing of aluminium acetate.
Nov. 7, 1914	$\frac{2 \times 7 \times 5}{8 \times 8}$	None	Same as before	H1¼ S.D.	Healing is complete; reaction has disappeared; no evidence of epithelioma; prophylactic treatment.
Jan. 15, 1915	....	....	....	....	Erythema after last treatment which lasted one week; clinical cure.
Jan. 22, 1918	....	....	....	....	No return of epithelioma; no sequelæ; almost imperceptible scar; photograph No. 870.

CHAPTER XI.

FILTERED ROENTGEN-RAY TECHNIC.

Before studying this chapter the student is advised to read the chapter on general physics and also the chapters dealing with unfiltered roentgen-ray technic.

Absorption.—The word penetration is used to denote the ability of roentgen rays (and radium rays) to pass into and through material that is impervious to light. It is preferable to visualize this characteristic in terms of absorption rather than as penetrability. In passing through matter some radiation is lost by absorption, and some is lost by scattering. The emerging beam is composed of secondary radiation, scattered radiation and the remainder of the original primary beam—hence the word penetration.

Absorption depends upon several factors. Rays of comparatively long wave lengths ("soft rays") are more readily absorbed than are those of short wave length ("hard rays"). Absorption, also, is roughly in proportion to the density of the material through which the radiation passes and, of course, varies with the thickness of this material.

Reduction of Intensity.—Reduction of intensity of initial radiation depends upon two factors: (1) The composite radiation spreading out from a small source decreases in intensity inversely as the square of the distance (page 40). (2) Reduction of intensity of radiation passing into or through matter is due to absorption and this absorption depends upon the wave length considered and on the density of the absorbing material. There is also a certain loss of intensity by scattering, such loss being difficult to estimate. There is no loss of intensity through absorption by air for distances used in practice. Furthermore, there is no change in quality (wave length) by distance. Ethereal waves in vacuum travel unchanged indefinitely unless obstructed by matter of sufficient density to effect absorption. Therefore, distance is not a filter.

The effect of wave length and density on absorption must be clearly understood. For a given substance absorption will depend upon wave length (page 42). The absorption of each wave length follows an exponential law, *i. e.*, successive layers of like thickness of a given material will absorb the same fraction of radiation received on its proximal surface. Thus, if 1 mm. of aluminium cuts down initial intensity 50 per cent. the second millimeter will reduce intensity to 25 per cent., the third millimeter to 12½ per cent., and so on. This rule ignores loss of intensity by distance, but such loss is negligible for a few millimeters of absorbing material because the source of radiation is usually at a distance of several inches (page 41).

It is important to note (page 43) that the proportionate rate of absorption for a given material in the case of rays of long wave length is very much greater than for those of short wave lengths.

The radiation from every roentgen tube is heterogeneous—composed of rays of different wave lengths. The wave length varies with the voltage. Radiation from a tube operated at a 9-inch spark gap will contain rays of shorter wave length than will radiation from the same tube operated at a 3-inch spark gap. But in either instance the composite bundle of rays is heterogeneous.

When this heterogeneous radiation passes through successive layers of aluminium of equal thickness absorption will not be exponential. At low voltage most of the radiation consists of long wave lengths. A very large part of such radiation will be absorbed by the first few millimeters of aluminium, very little being left for absorption by the deeper layers. Conversely, with high voltage, where there are more short waves than long waves there will be a more uniform absorption throughout many layers of aluminium. Furthermore, after *x*-rays have passed through from 4 to 6 mm. of aluminium, the radiation is practically homogeneous. Absorption of such radiation will be approximately exponential.

What has been said relative to absorption of radiation by aluminium is true for human tissue. Ignoring loss of intensity by distance and the fact that human tissue varies somewhat in density, absorption for any given wave length follows an exponential law. The author is not aware of any accurate experiments that have been made to determine the comparative absorption coefficients of animal tissue and aluminium for roentgen rays obtained under given working conditions. Perthes found that absorption by most animal tissue was about the same as water. Using water as the absorbing medium he found that aluminium is from seven to ten times as effective an absorber of *x*-rays as is animal tissue. But as pointed out by Colwell and Russ this is nearly three or four times as much as its density would suggest. It would seem then that 1 mm. of aluminium will absorb about the same amount of radiation as will be absorbed by about 7 mm. of average animal tissue. The amount of absorption in a given thickness of aluminium or tissue will depend, as we have already seen, on the wave length. About 50 per cent. of a 70,000 volt radiation (6-inch gap) will be absorbed by 3 mm. of aluminium (Hull). The percentage will be less for a 9-inch gap and greater for lower voltage (page 43).

Filtration.—By filtration or screening, is meant the interposition of some more or less impervious material through which the rays must pass before reaching the surface to be irradiated.

Choice of Filtering Material.—In roentgen therapy all sorts of material have been used for this purpose. Many years ago Pfahler suggested the use of wet sole leather. At various times during the evolution of deep roentgen therapy different roentgenologists have

advised chamois, felt, aluminium, lead foil, and other metals and organic substances.

Aluminium has been for a number of years and still is the popular filter. There are fairly definite reasons for this popularity: First, there are no reports of radiodermatitis resulting from the secondary radiations from aluminium even when the metal is placed in contact with the skin. In this connection, Whiddington has detected a very "soft" type of secondary radiation from this metal which he considers characteristic. However, there is no evidence that such radiation can cause injury.

Second, aluminium is light and easily handled. It can be obtained as foil in thicknesses of 0.1 mm. Sheet aluminium ½ mm. or 1 mm. thick can be cut to match the shape and size of the diaphragm of the tube stand. A number of such discs permit light or heavy filtration. The low density of the metal permits the use of greater thickness, therefore reducing the danger of error when measuring thickness or uniformity of thickness of the filter.

Table I shows the filtration equivalents for various absorbing materials used in connection with "hard" rays (Salmond).

Table I.—FILTRATION EQUIVALENTS FOR "HARD" RAYS (SALMOND).

Aluminium.	Compressed paper.	Tanned leather.	Chamois leather.[1]	Boiler felt.	Lead acetate lint.[2]	Sodium tungstate lint.[3]
Mm.	Mm.	Mm.	Mm.	Mm.	Layers.	Layers.
0.5	3	3	10	13	1	2
1.0	7	7	18	30	2	4
2.0	13	13	35	67	4	8
3.0	17	16	59	97	6	12

Ordinary glass (soda-glass) is said to have about the same absorption coefficient as aluminium. Glass, chamois, felt, leather and paper do not, so far as is known, give rise to injurious secondary rays.

Object of Filtration.—Rays emitted by a roentgen tube are filtered by the glass wall of the tube. It is for this reason that there is very little radiation emitted when working with a one-inch spark gap as measured by practical methods of intensity estimation. Nevertheless, rays emitted by a roentgen bulb are spoken of as unfiltered. The glass wall of the Coolidge tube is always of the same thickness. Great care is used to prevent differences in thickness and composition of the glass. Wertheim-Solomonson describes a practical method of estimating the thickness of the wall of a roentgen tube which may be of interest to those desiring to detect possible variations in thickness. (Reference at end of chapter.)

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[1] Known as London board.

[2] Hospital lint or gauze soaked in a saturated solution of lead acetate and allowed to dry.

[3] Gauze similarly treated with sodium tungstate.

When working at high voltage (9-inch gap) the radiation is said to be "hard," *i. e.*, it contains short waves that are not easily absorbed. But it will be recalled that no matter how high the voltage or the type of tube, the beam of radiation contains "soft" and "medium" rays that are readily absorbed by superficial tissue.

When treating any but very superficial lesions it is often desirable to apply a lethal dose or at least a therapeutically efficient dose to the lowermost part of a thick lesion, or to a subcutaneous lesion, with as little effect on the more superficial tissues as is possible. It is not practicable to have radiation pass through superficial tissue without absorption, but it is possible to use a quality of radiation that is, because of its penetrability, more equally absorbed throughout a given depth (page 44). The more penetrating the radiation the greater will be this equalization of intensity for the reason that successive layers of superficial tissue absorb proportionately less than with less penetrating rays. A filter or screen of sufficient thickness and density absorbs all but the short wave lengths. Such radiation is therefore more homogeneous as it is composed only of rays of short wave length.

It should be clearly understood that filtered rays are not more penetrating than are unfiltered rays obtained from the same source. The filter does not shorten the wave length but simply removes all but the short wave lengths. Inasmuch as the bulk of the radiation from a tube even when operated at high voltage, consists of "soft" and "medium" rays, heavy filtration causes an enormous reduction of intensity, but this loss of intensity is compensated by increased time of exposure. The loss of intensity by filtration in the case of x-rays is not as annoying as with radium. In the former it is possible to compensate by time of exposure, shortening the distance, or by the use of high ampèrage. With radium it is necessary to use more of the element or to increase enormously the time. The filtered radiation from a Coolidge tube operated at high voltage and say 5 milliampères of current will give the intensity of several grams of radium under the same conditions of filtration (Eve; Russ).

This is true only for comparatively light filtration. Several millimeters of lead will cut down the intensity of the roentgen rays to practically nothing while it requires several centimeters of lead to eliminate the gamma rays of radium.

The student should also realize that even heavily filtered rays are absorbed to a greater extent by superficial than by deep tissue. The difference is simply that the proportion of absorption by superficial tissue is less for short wave lengths than for long wave lengths. This is repetition but the subject seems to be so difficult for the beginner to grasp that reïteration is justifiable. Loss of intensity of heavily filtered rays—let us say homogeneous rays of short wave length—when traversing successive layers of human tissue, ignoring distance, scattering, secondary rays and differences in density, for practical purposes may be said to follow an exponential law. If the first centimeter should

absorb arbitrarily, 10 per cent., reducing initial intensity to 90 per cent., the second centimeter will absorb 10 per cent. of the radiation that has traversed the first layer, etc.

The point to be emphasized is that it is impossible, by means of filtration, to apply a larger amount of radiation to a deep-seated cell than to a more superficial cell; the reverse is true. Insofar as concerns the radiation the biologic effect is probably due to the quantity absorbed and has little directly to do with the wave lengths (page 44). Pathological cells, physiologically active cells and lymphoid tissue are very susceptible to irradiation. It is often necessary to effect such tissue when situated at varying depths under the normal skin. Filtration, by causing a more uniform equalization of intensity throughout the desired depth, will provide the means for obtaining the desired effect on susceptible tissue situated under the surface without undue injury to the more resistant overlying tissue.

Thickness of Filter.—Physicists have devoted a great deal of time to the study of filtered *x*-rays, and a great deal has been accomplished, but very little appears to have been done in recent years to determine the best filtering material or to establish a comparative absorption scale for definite thicknesses of such material as compared with tissue absorption. In other words filtration has not yet been standardized. What is required is reasonably definite knowledge regarding the thickness of aluminium or other material to be used when treating pathological tissue at varying depths, intensity charts that indicate intensity of filtered radiation at varying depths, etc.

For years it has been customary to use 3 mm. of aluminium for purposes of filtration. Pfahler now employs 6 mm. of this metal or its equivalent in glass. It is probable that 6 mm. of aluminium absorb all but the more penetrating radiation from roentgen tubes now used in practice. The radiation traversing this amount of aluminium is thought to be fairly homogeneous.

There is a difference of opinion regarding the desirability of using different thicknesses of aluminium (from 0.1 mm. to 1 mm.) for the treatment of superficial conditions. There may be some advantage in employing filtering material that will absorb rays that otherwise would be absorbed by the epidermis, in the treatment of conditions that are in the true skin—or in diseases that produce a marked thickening of both the epidermis and derma. The author, however, is not convinced of the advantage of a thin filter in very superficial affections except in instances that will be discussed later. Filtration is not as important in roentgen therapy as in radium therapy because with radium both the beta rays and the soft gamma rays must be excluded excepting when treating very superficial conditions. Furthermore, in radium therapy, filtration to some extent offsets the disadvantage of having the source of radiation close to the skin. The question of filtration in superficial affections is discussed at greater length in Chapter XIX.

Position of Filter.—It is customary to place the aluminium in the diaphragm of the tube-stand, a holder being provided for this purpose. Roughly, this position is about half way between anode and skin. Insofar as concerns accuracy the position of the filter is of no importance. Secondary rays play an important rôle in filtered work but injurious secondary rays are obtained only from the heavy metals. When heavy metals are used as absorbing material they should be covered with chamois, glass or leather to absorb the "soft" secondary radiations. Aluminium seems to be safe in this respect although many roentgenologists take the precaution of using two or three layers of ordinary chamois or other suitable substance to protect the patient against injury by "soft" radiations. Some operators place the filter on the skin or very close to the skin and then connect it to the ground to prevent sparking. Such practice is inadvisable as all grounds close to the patient increase danger of electric shock.

Wave Lengths Suitable for Filtration.—Other than for reasons of economy it is questionable if the voltage or spark gap length makes any difference, in the voltage range used in superficial therapy. With a 3- or 4-inch spark gap the amount of radiation passing through the filter will be far less than with a 9-inch gap because with high voltage there is an increase of short wave lengths as well as an increase in long wave lengths. Increasing the voltage increases intensity, ampèrage remaining the same. At high voltage there are rays of shorter wave length than with low voltage so the quality after filtration for the two extremes would be different. Penetration increases rapidly from a 3-inch gap to a 6-inch gap after which the increase is relatively slight (page 40). In practice it is customary to use either a 7-inch gap or a 9-inch gap (80,000 to 100,000 volts). There is probably not a great deal of difference in the quality of radiation from tubes operated at these voltages after the radiation has passed through the filter, but there is a rather marked difference in intensity. Therefore, if for no other reason than one of economy it is preferable to employ a 9-inch gap in filtered work.

Filtration Dosage.—There is no unanimity of opinion relative to filtered dosage. Some authors aver that it is possible to give two, four, ten and many more times the erythema dose of filtered rays without injurious effects. Statements like this do not mean much unless accompanied by explicit technical details. Two minutes with certain factors will effect an erythema with unfiltered radiation. The same radiation filtered through 3 mm. of aluminium requires within a few seconds of twenty minutes to produce an erythema. One might say as a result of the difference in the time factor that 10 erythema doses were applied—but such a statement would be misleading.

We find the same discrepancies when we analyze dosage as estimated radiometrically. At society meetings it is common to hear of a dose of 50X and higher with 3 mm. of aluminium administered at one sitting. The author has never been able to give these enormous doses without injury to the skin.

One writer avers that a Sabouraud pastille dose of 1B of unfiltered radiation is dangerous while double this amount (2B) will certainly provoke an injurious reaction. There is no chance for argument so far. But in comparison it is stated that from 50 to 100B, filtered through 4 mm. of aluminium can be administered with safety. B1 is the equivalent of H5 which corresponds to 10X. Therefore, the maximum dose is H 500 or 1000X. The author has repeatedly obtained an erythema with a dose of H2½ with the pastille on the skin and 3 mm. of aluminium between the pastille and the tube (20X). Insofar as concerns the pastille this is only double the amount required for the same superficial effect as compared with unfiltered rays. That is, a pastille reading of H1¼ skin distance, is the erythema dose for unfiltered rays while a pastille reading of H2½ is required for the erythema dose with filtered rays (3 mm. Al). But this does not mean that the skin has received only double intensity. There is only one point where the skin effects and pastille effects can be compared—at the point in intensity or quantity where an erythema is produced. Starting at the erythema dose and doubling the time factor, all other factors remaining the same, intensity at the skin is doubled, but the pastille does not give double reading on the Holzknecht radiometer. A pastille dose of H2½ with filtered rays will require an enormous increase in the time factor as compared to that used to obtain the same pastille reading with unfiltered rays, assuming that all other factors are constant. A pastille reading of H2½ at full distance with unfiltered rays will be obtained in three and three-quarter minutes with the following factors: Sp. G. 9, Ma. 5, D. 10 in. With the same factors and 3 mm. of aluminium the pastille reading of 2½ is obtained by increasing the time factor to thirteen minutes (12′ 50″). If this change in time is used as a basis of intensity computation, ignoring the effect of filtration, the total dose might be estimated at 80X (H2½, skin distance, H10 half distance, 20X, in 3 m. 45 sec., multiplied by 4, which represents the approximate increase in time, yields 80X). This may be one explanation for the large doses found recorded in the literature.

The increase in time is caused by two factors: (1) Reduction of general intensity and (2) the excessive reduction in those wave lengths that would have been entirely absorbed in the skin or almost entirely absorbed in the superficial layers of tissue. Rays of short wave lengths are not so easily absorbed by the first few millimeters of tissue as are rays of long wave lengths, therefore to obtain the same visible effect on the skin it is necessary to apply a larger amount when employing filtered rays. Still another point which has led to confusion is the fact that pastilles lose in sensitiveness as they gain in color. Working with 3 mm. of aluminium and other fixed factors (Ma. 5, Sp. G. 9 in., D. 10 in.) it will require two minutes and thirty-four seconds to color a pastille to H1, the pastille being placed at skin distance. If the time factor is doubled (five minutes and eight seconds) intensity is doubled, but the pastille will show H1½ instead of H2.

Technic Advised by the Author.—This technic, which has evolved from work done by Shearer, and by Remer and Witherbee, is advised for the beginner. It will be found safe and practicable although not particularly versatile. The technic is standardized by ascertaining the time required to obtain an erythema with a given set of constants, the time factor then being divided into fractions and plotted on a chart. An operator may select any set of constants and standardize a technic by experiments on the skin (page 135). To obviate the necessity of such effort dose charts for several sets of constants have been prepared and are herewith appended.

These charts, or the technic they represent, were obtained in the following manner: The constants were first decided upon and then carefully maintained throughout the exposure. A pastille was placed on the table (representing anode-skin distance) and exposed until it read H2½ (H2½ having been established by Remer and Witherbee as the erythema dose for filtered radiation). Thus the time factor for this set of constants was established. The next step was to expose a small area of normal human skin to radiation produced by this set of constants in order to verify by skin effects the result recorded by the pastille. The final step consists of plotting the technic on a chart in such manner that the time factor is shown for various fractional parts of the erythema dose.

Dose charts have been made for various sets of factors. The distance and milliampèrage is the same in every instance. The other constants vary:

Chart 13. Ma. 5; Sp. G. 9; distance 10 inches; filter 3 mm. aluminium.

Chart 14. Ma. 5; Sp. G. 7; distance 10 inches; filter 3 mm. aluminium.

Chart 15. Ma. 5; Sp. G. 9; distance 10 inches; filter 1 mm. aluminium.

Chart 16. Ma. 5; Sp. G. 7; distance 10 inches; filter 1 mm. aluminium.

Chart 17. Ma. 5; Sp. G. 9; distance 10 inches; filter ½ mm. aluminium.

Chart 18. Ma. 5; Sp. G. 7; distance 10 inches; filter ½ mm. aluminium.

While H2½ S.D. has been established as the erythema dose (pastille measurement) for filtered radiation, it seems preferable to reduce this standard amount for general work. The reason for this reduction is that H2 S.D. will effect an erythema on such sensitive parts as the face, abdomen and flexures in young subjects. The erythema dose given in the charts is H2 S.D. The filtered epilating dose is: minimum, H1½ S.D.; average, H2 S.D.; maximum, H2½ S.D.

It will be noted that the technic is based upon the erythema dose as measured by pastille and verified by skin effects. At this point there is an agreement with pastille measurement. The fractional doses, obtained by division of the time factor, are not in accord with pastille measurement and cannot be given in terms of Holzknecht units. This difference is due to a pastille characteristic which has been explained. It is advisable, in using this technic, to think of the erythema dose as an arbitrary unit (filtered unit) which corresponds to H2 S.D., and

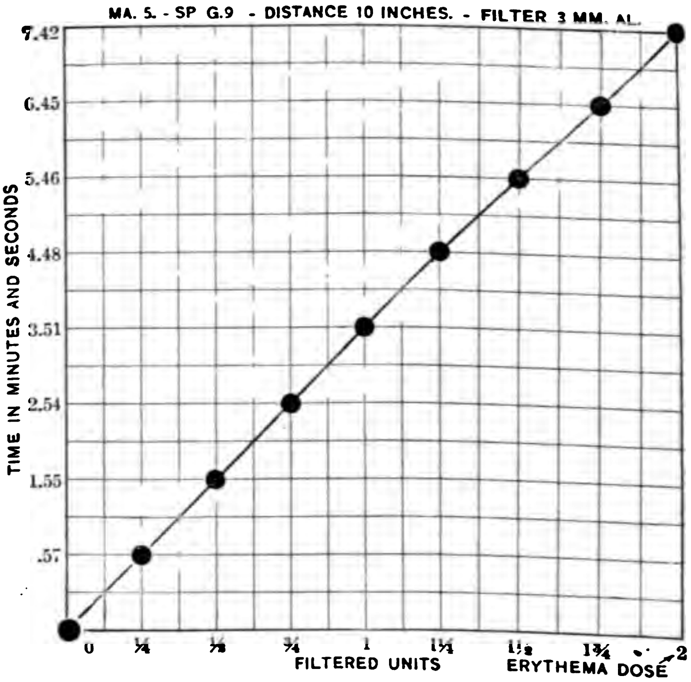

Chart 13.—Dose chart for filtered *x*-rays.

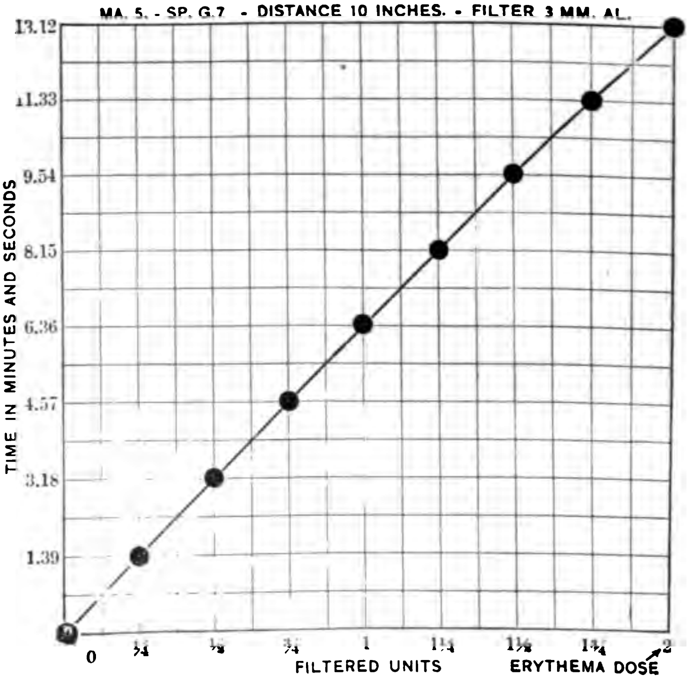

Chart 14.—Dose chart for filtered *x*-rays.

3:33

[illegible]

4. [illegible]

2, [illegible]

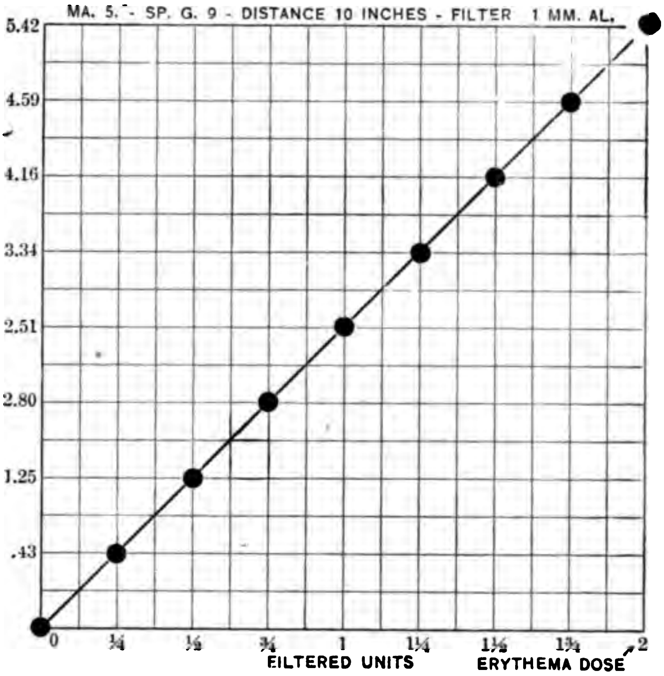

CHART 15.—Dose chart for filtered *x*-rays.

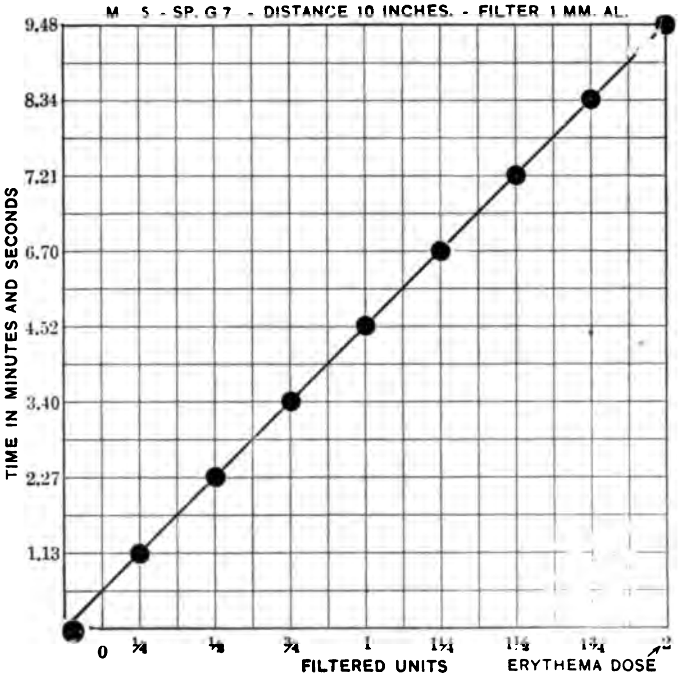

CHART 16.—Dose chart for filtered *x*-rays.

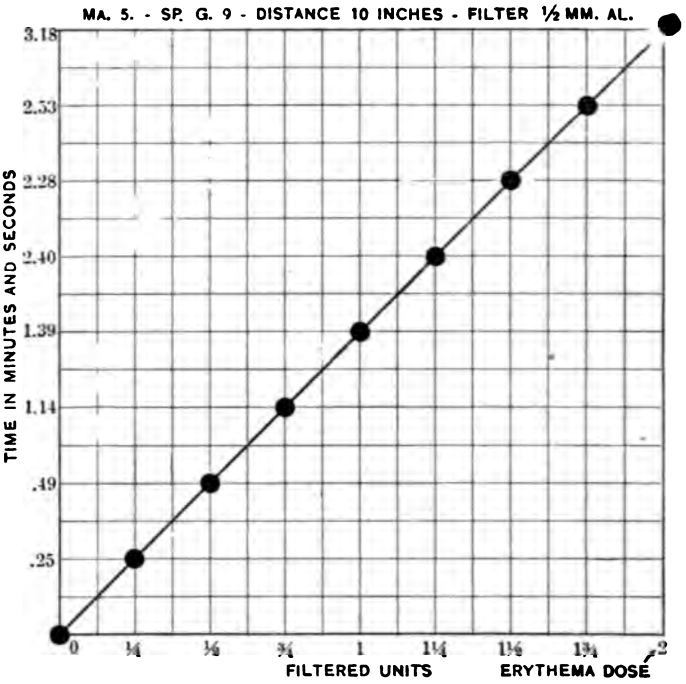

Chart 17.—Dose chart for filtered *x*-rays.

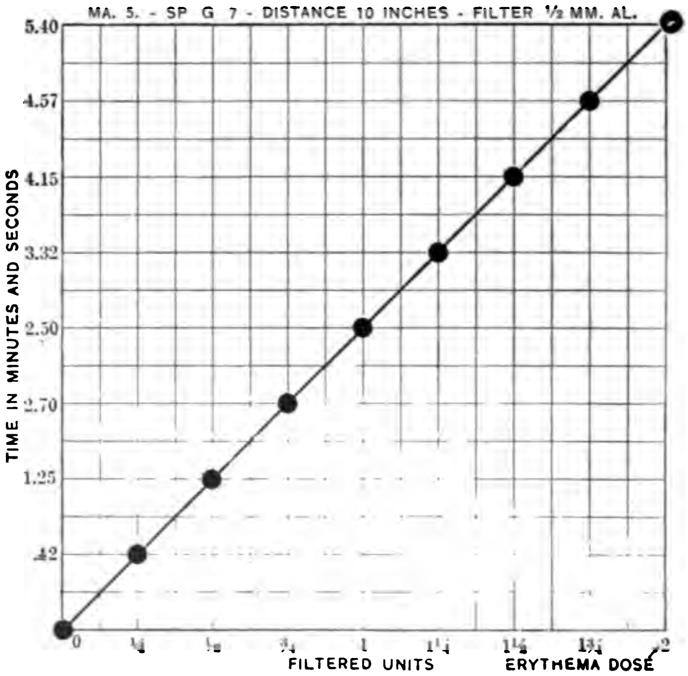

Chart 18.—Dose chart for filtered *x*-rays.

fractions thereof as constituting fractions of this filtered unit but not as fractions of H units. Fractions of a filtered unit may be added to the filtered unit to obtain hyperintensive and ultraintensive doses.

It is a good plan for the operator to make copies of the charts and place them on or near the switch-board. The operator must be certain of his constants (Ma., Sp. G., distance, time and filter) throughout the entire exposure. It is important to note that distance means the distance from anode to skin. Only aluminium can be used.

The author knows of five instances where operators administered a heavy dose supposedly of filtered radiation, but found that they had failed to insert the filter. It should be a rule not to close the switch until the filter is in position.

The operator may change the milliampèrage and voltage if he so desires, the result being computed in accordance with the laws:

1. Intensity varies directly as the voltage (pastille and skin effects).
2. Intensity varies as the square of the voltage (photographic measurement).
3. Quantity varies directly as the time (photographic and skin effects).

In explanation it may be stated that in both filtered and unfiltered work intensity is doubled when the length of the spark gap is doubled if intensity is estimated by pastille or by visible skin effects. When the photographic method of estimation is used, intensity increases four times when the spark gap is doubled. The difference existing between pastille and photographic measurement in this respect may be one reason for the large doses reported in the literature.

In regard to the third law it has been found that in filtered work doubling the time doubles quantity as estimated by visible skin effects and by photographic measurement. The pastille does not obey this law. This is not surprising when it is recalled that a pastille loses in sensitiveness as it increases in color. Time must be increased for reduced current, and *vice versa*, and in exact proportion, all other factors remaining the same. Thus for 3 instead of 5 milliampères we must use $\frac{5}{3}$ as long exposure time.

If the composition or thickness of the filter is changed it is necessary to restandardize the technic.

Regarding changes in the anode-skin distance it will be recalled that for unfiltered radiation intensity varies inversely as the square of the distance. In filtered work Remer and Witherbee claim that intensity varies inversely as the distance—that if distance is cut in half intensity will be doubled instead of being four times greater. They used pastille measurement and arithmetical computation and in two instances their results were verified by experiments on human skin.

Their results have not been corroborated. In fact physicists have demonstrated that the inverse square of the distance law holds for filtered radiation as well as for unfiltered radiation. Too much reliance must not be placed on skin effects because especially with

filtered radiation an erythema is not a good criterion of the amount of radiation reaching the surface. A certain amount of heavily filtered radiation will cause an erythema. Now considerably more filtered radiation might be administered without provoking much additional erythema. In both roentgen therapy and radium therapy, where heavy filters have been employed, the author has seen treatment continued in the presence of erythema. The erythema was not materially enhanced, but eventually ulceration set in and extended through the subcutaneous and muscular tissues. An erythematous reaction may be employed for the purpose of standardizing a technic in practical work or for designating a practical dose, but it is unwise to attempt to establish definite physical laws by pastille measurement or by skin effects.

TABLE II.—DOSE TABLE FOR FILTERED RAYS. MA. 5. DISTANCE 10 INCHES. FILTER, 3 MM. AL. (REMER AND WITHERBEE.)

Sp. G.	Time. Minutes and seconds.	Pastille readings. Skin distance.
6	3′ 51″	1
6	7′ 42″	1¼
6	11′ 33″	1½
6	15′ 24″	1¾
6	19′ 15″	2
7	3′ 18″	1
7	6′ 37″	1½
7	9′ 54″	1¾
7	13′ 12″	2
7	16′ 30″	2¼
7	19′ 48″	2½
7	23′ 68″	2¾
7	26′ 28″	3
8	2′ 53″	1
8	5′ 46″	1½
8	8′ 39″	2
8	11′ 32″	2¼
8	14′ 25″	2½
8	17′ 18″	2¾
8	20′ 11″	3
9	2′ 34″	1
9	5′ 88″	1½
9	7′ 42″	2
9	10′ 16″	2¼
9	12′ 50″	2½
9	15′ 24″	2¾
9	17′ 58″	3
10	2′ 19″	1
10	4′ 38″	1½
10	6′ 57″	2
10	9′ 16″	2¼

Roentgenologists desiring to use pastille doses instead of arbitrary filtered units will find Table II of service. The doses are estimated by the pastille method, the pastille being on the skin, and are recorded in Holzknecht units. For each spark gap H2 or H2½ may be regarded

as the erythema dose—the smaller dose for sensitive skin and the larger dose for less sensitive skin. It will be noticed that with any spark-gap length, doubling the time does not double the dose as given in H units. For instance, with a 9-inch gap it requires two minutes, thirty-four seconds to obtain H1 as measured with a pastille on the Holtzknecht radiometer. Double the time to five minutes, eight seconds and the pastille reading is H1½. To double the pastille dose will require seven minutes, forty-two seconds. This is due, as previously explained, to a fault in the pastille method of measurement. If time is doubled so is quantity but not as measured by the pastille. It must be understood, therefore, that the doses recorded in this table are Holzknecht units at skin distance.

Arithmetical Computation.—No one has yet formulated a perfectly satisfactory arithmetical method of estimating filtered *x*-ray dosage. Remer and Witherbee have worked out a complicated arithmetical method based upon pastille measurement. Their work has not yet been verified. The reader should also study the system advocated by Mazérès. Those who are interested will find the necessary references at the end of the chapter.[1]

Estimation of Dosage Below the Surface.—One fault with all forms of measurement of intensity in roentgen therapy, is that intensity is estimated at the surface of the part irradiated. There is no standard method of estimating intensity at a given depth. Such estimations are approximate. In attempting approximate estimations of intensity at a given depth there are two facts that must be kept in mind: first, loss of intensity by distance and, second, loss of intensity by absorption. Figures for loss of intensity by absorption will be found on pages 41 and 43. In this connection Guilleminot, years ago, prepared a table to show the (approximate) rate of absorption for different thicknesses of human tissue with filtered and unfiltered roentgen rays (Table III). Eliminating loss of intensity by absorption the loss by distance will be inversely as the square of the distance.

Increasing the distance of the source of radiation tends to equalize intensity throughout a given depth. At great distance the amount of radiation received at a given depth, in relation to the amount received at the surface, is greater than at short distance. This is due to the fact that with the source of radiation at a distance the rays are more perpendicular and therefore they are not lost by spreading out obliquely (in a fan-shape manner) as they pass through the tissue. Referring to Fig. 2 (Chapter II), *F* is the focal spot on the target; *A B C D*, a surface area receiving radiation; *I J K L* would receive the same radiation at the greater distance from *F* that *A B C D* receives at the nearer distance. Hence an equal area at the greater distance receives less, *i. e.*, *E F G H* receives less radiation than *A B C D*. Note that each area of the rectangular prism *A G*, as we go down, receives less radiation because rays entering the prism pass out through its lateral

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[1] See, also, article by J. S. Shearer, Am. Jour. Roentg., 1921, viii, n. s., p. 154.

walls. As the target is moved farther away the rays becomes more nearly parallel to the edges A E, and less radiation leaves through the sides of the prism.

Another way in which intensity can be increased in the deeper tissue is by cross-fire. A discussion of cross-fire methods will be found in Chapter XIX.

In the last few years the German roentgenologists, for purposes of deep therapy, have used a twelve- to fourteen-inch spark gap, a very heavy filter (10 or 12 mm. aluminium or the equivalent in some other metal) and a very long skin-target distance—several feet. This combination provides a fairly homogeneous, perpendicular radiation of very short wave length. The loss of quantity by distance and low milliampèrage necessitates very long exposures. Whether or not the results will compensate for the handicaps of great distance, extreme voltage and low ampèrage, remains to be seen.

TABLE III.—DEPTH OF TISSUE PENETRATED BY *X*-RAYS.

Quality of rays.	Surface.	Depth of tissue.								
		5 cm.	1 cm.	2 cm.	3 cm.	4 cm.	5 cm.	6 cm.	7 cm.	8 cm.
4 Benoist	Dose transmitted, 100	65	43	22	13	8	5.2	3.8	2.6	1.8
5 “	“ “ 100	72	53	32.5	21.9	15.5	11.6	8.8	7.0	5.5
6 “	“ “ 100	78	63	44	33	26	21	17.2	14.4	12.0
7 “	“ “ 100	81	68	50	39	32	26.5	22.8	19.7	17.2
8 “	“ “ 100	83.2	69.9	52.7	42	34.8	29.5	25.5	22.3	19.6
Filter										
8 “ 1 mm.	“ “ 100	86.5	76.2	61.1	50.6	43	37.3	32.6	28.5	25.4
8 “ 2 mm.	“ “ 100	89.2	80.4	67	57.1	49.4	43.3	38.2	33.8	30.1
8 “ 3 mm.	“ “ 100	91	83.5	71.8	61.8	54.5	48.0	42.5	37.8	34.8
8 “ 4 mm.	“ “ 100	92.8	86	74.5	65.4	57.8	51.3	45.7	41.0	37.0
8 “ 5 mm.	“ “ 100	95	87	76.1	67.2	60	53.8	48.5	44.0	40.2

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CHAPTER XII.

RADIUM TECHNIC.

BEFORE reading this chapter the student should study the preceding chapters, at least those portions of preceding chapters that deal with radium and the radioactive substances. As a preface to an explanation of the phenomena inherent to a radium applicator we will review briefly the decay of radium.

Decay of Radium.—Radium is an unstable element the atoms of which undergo spontaneous disintegration with the formation of new elements. This disintegration follows an exponential law, *i. e.*, the rate of decay per gram is constant. The disintegration is, however, very slow, the half value period being one thousand six hundred and ninety years. In other words a gram of radium today will be reduced to one-half gram in sixteen hundred and ninety years.

The first phenomenon in the decay of radium is the expulsion of an alpha particle from the atom. The atom is now one of radium emanation whose half value period is 3.85 days. The emanation atom now liberates an alpha particle, the remaining atom being one of radium A, a solid substance with a half value period of three minutes. This in turn is changed to radium B (half value period 26.7 minutes) and then into radium C (half value period 19.5 minutes). Radium A, radium B and radium C constitute the active deposit of quick change.

It will be noted that the element radium emits alpha rays only. The next product, radium emanation, also emits only alpha rays. The radiation used in therapy, namely, beta and gamma rays, originate from radium B and C. A fresh sample of radium or of radium emanation is, for a minute or two, free from beta and gamma rays, but as will be seen later the increase in beta-gamma ray activity is rapid after the first few minutes. Inasmuch as radium and its emanation are the source of the same decay products it is obvious that either may be employed therapeutically.

Phenomena of a Radium Applicator.—It may help the beginner to visualize and appreciate the above mentioned phenomena and their importance in the practical application of radium, to visualize the process of decay of a definite amount of the element in a sealed glass container—a radium tube applicator. Let us assume that when the radium is placed in a tiny glass tube it is free of its subsequent products. As soon as the tube is sealed emanation collects at a constant rate because a definite number of radium atoms are disintegrating per second. At the same time the emanation atoms are disintegrating. The number of emanation atoms that disintegrate per second depends

upon the total number present. At first, when the amount of emanation is small, the number of emanation atoms undergoing disintegration per second is less than the number of radium atoms decaying per second. Emanation will, therefore increase in quantity. Finally, however, the number of emanation atoms decaying per second will equal the number of radium atoms decaying per second, after which there can be no increase in the amount of emanation. The same rules may be applied to the subsequent products. In other words, the same number of atoms of each substance are disintegrating per second—radium and its products are in equilibrium.

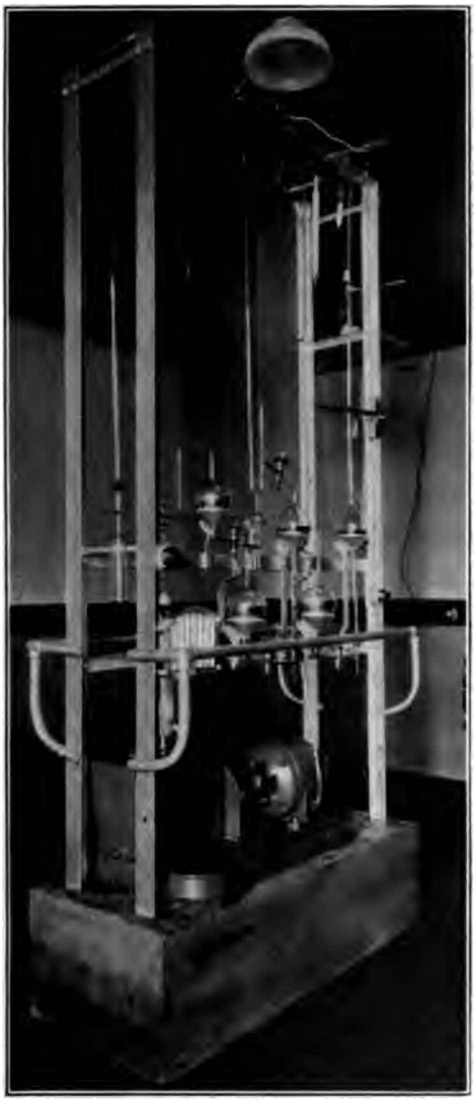
When the radium is first placed in the tube there is no beta or gamma radiation. Beta and gamma radiation does not occur until the active deposit is formed and does not reach maximum until equilibrium. The preparation begins to be feebly radioactive in a few hours. It is still about ½ per cent. short of maximum at the end of a month. After equilibrium there is no change in radioactivity excepting that due to the slow disintegration and loss of radium element (half value, sixteen hundred and ninety years).

Collection of Radium Emanation.—A radium salt, usually the chloride or bromide, is dissolved in a very weak solution of hydrochloric acid and placed in a glass flask. This in turn is kept in a heavy vault or safe from which it is never removed. The safe is 3 or 4 feet above the floor. The glass container is connected, by glass tubing, with the collecting and purifying apparatus. The apparatus consists essentially of two parts—the collecting system and the purifying system. The method of collecting emanation does not differ materially from that used by physicists for many years. Originally, purification was effected by means of liquid air, but Duane changed the purifying system by substituting suitable chemicals.

The apparatus shown in Fig. 49 is the type mostly used in this country and was designed by Failla and described in a recent publication by Viol. The following detailed description and photograph of the apparatus is taken from Viol's article. Inasmuch as most of the apparatus consists of glass flasks, tubing and cocks which are often broken, it is advisable to have all these parts in duplicate and so arranged that the emanation may be shifted to the duplicate parts by the turning of a cock. This avoids delay in case a flask or a tube is broken while emanation is being collected. Fig. 50 is a diagrammatic representation of the essential working parts of the apparatus.

Referring to Fig. 50, 1 represents the glass flask containing the radium solution which is kept in a suitably constructed safe. A properly constructed tube connects this flask with the apparatus, the two being connected or disconnected by the valve at 2. Accumulated emanation is collected as follows: With the vacuum pump running and stop cocks 22 and 8 set to give a vacuum in the line A, cock 6 is opened, allowing mercury to pass from vessel 4 to vessel 7, the mercury level being maintained just above 5, by closing 6. This permits the accumulated emanation, water, vapor, hydrogen, oxygen, etc., to

y diffuse into vessel 4. By turning cock 22 air is admitted through ying tube 23 to the line A communicating with vessel 7, and on ng cock 6, air pressure raises the mercury into vessel 4, forcing



o. 49.—Apparatus used for collecting and purifying radium emanation; without duplicated parts. (Viol.)

he emanation over into vessels 9, 10 and 11 when the sodium hydroxide, the heated copper oxide spiral and phosphorus pentoxide absorb carbon dioxide, hydrogen, moisture, etc. Vacuum is again established in line A, stop cocks 8 and 6 having been closed and on opening cock 14,

mercury flows from vessel 12 into vessel 15. This permits the purified emanation to diffuse into vessel 12. Air is again admitted to line A and the mercury level in the U-shaped tube 17 is raised above the base of the U by opening cock 20 which is then again closed. Cock 14 is then opened and the mercury passes from vessel 15 into vessel 12, compressing the emanation in the tube at cock 16. This cock is then

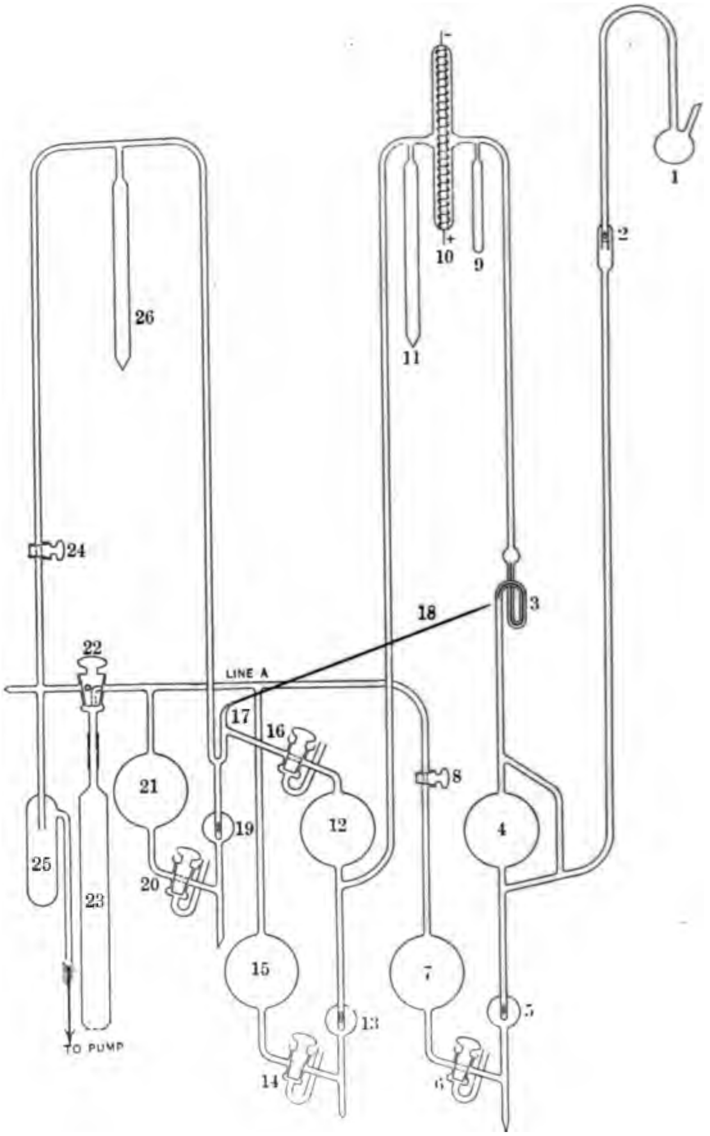


FIG. 50.—Schematic drawing of radium emanation apparatus. (Viol.)

opened momentarily to allow the emanation to pass through. The whole operation is repeated until all emanation has been forced past cock 16. By again opening cock 20, the mercury from vessel 21 forces the purified emanation up into the left branch of 17 and thence out into the capillary tube 18. As the difference in level of the mercury in 21 and in 18 is only a few centimeters, the emanation is under reduced pressure and upon heating the capillary tube with a fine flame the glass softens, falls together and the tiny emanation tube can be drawn off without loss of emanation.

The entire process is repeated daily to secure the emanation that has meanwhile accumulated. The capillary tube containing the emanation, which has about the diameter of a hypodermatic needle, is divided into a number of individual tubes, about ½ inch in length, by means of the flame.

When prepared, emanation tubes do not emit beta or gamma rays. Beta-gamma ray activity begins in a few minutes and reaches a maximum in three and a half hours. Table IV (after Viol) shows this initial increase in beta-gamma ray activity.

TABLE IV.—INITIAL INCREASE IN BETA-GAMMA RAY ACTIVITY IN A RADIUM EMANATION PREPARATION DUE TO THE ACCUMULATION OF THE ACTIVE DEPOSIT (RADIUM A, RADIUM B, AND RADIUM C). (After Viol.)

Time.	Activity. Maximum equals 1000.
0	0.000
10 min.	0.039
20 "	0.119
30 "	0.218
40 "	0.321
50 "	0.420
1 hr.	0.511
1 " 10 min.	0.593
1 " 20 "	0.663
1 " 30 "	0.723
1 " 40 "	0.774
1 " 50 "	0.817
2 hrs.	0.852
2 " 10 "	0.881
2 " 20 "	0.904
2 " 30 "	0.923
2 " 40 "	0.939
2 " 50 "	0.960
3 hrs.	0.970
3 " 30 " approximately	1.000

Because of the absence of beta and gamma rays in freshly prepared emanation it is not necessary to protect the assistants who collect the emanation providing the emanation is collected and disposed of quickly. The lead and steel contained in the safe is ample protection from the radium itself. As soon as made the emanation tubes are marked for identification and placed in small boxes made of very heavy lead, not being used until the beta-gamma radiation has reached a maximum of intensity. After three and a half hours the beta-gamma

ray activity decreases at the same rate as the decay of the emanation, half of any activity being lost in 3.85 days.

As we have seen, practically all of the beta and gamma rays used in therapy emanate from the active deposit of quick change—in fact from radium B and radium C. This active deposit may be and is used for therapeutic purposes. While the half value period is only about one-half hour yet the beta-gamma ray output is exceedingly intense. It is sometimes placed on lead foil for surface application, and on minute particles of soluble or insoluble matter for injection into the tissues.

Referring again to Fig. 50 active deposit is collected by allowing the emanation to pass into a special glass vessel which is sealed to the apparatus at 17. For an applicator the lead or other metal plate which is to be activated, is so exposed in the vessel as to permit the active deposit to form on the desired surface. When a solution is to be prepared, finely powdered salt is placed in the vessel. Emanation is admitted to the vessel for three or four hours to permit the maximum of active deposit to form. The emanation is then removed from the vessel by suitable manipulation and the vessel is removed from the apparatus. A solution of active deposit is prepared by dissolving the salt in water.

The decay of radium and the accumulation of emanation occur at about the same rate but, of course, the phenomena are reversed. Radium emanation will decay 50 per cent. in about four days but in the same time a radium preparation that is initially free from emanation will provide 50 per cent. of the equilibrium amount of emanation. Table V (after Kolowrat) gives the data relative to the decay of radium emanation and its rate of production in a radium preparation initially free from emanation.

TABLE V.—DECAY AND GROWTH OF RADIUM EMANATION.
(After Kolowrat.)

Time.				Time.			
Days.	Hours.	A.	B.	Days.	Hours.	A.	B.
	0	1.00000	0.00000	1	22	70822	29178
	1	0 99253	0.00747	1	23	70293	29707
	2	98511	01489	2	0	69768	30232
	3	97775	02225	2	1	69246	30754
	4	97045	02955	2	2	68729	31271
	5	96319	03681	2	3	68215	31785
	6	95600	04400	2	4	67706	32094
	7	94885	05115	2	6	66698	33302
	8	94176	05824	2	8	65705	34295
	9	93473	06527	2	10	64726	35274
	10	92774	07226	2	12	63763	36237
	11	92081	07919	2	14	62813	37187
	12	91393	08607	2	16	61878	38122
	13	90710	09290	2	18	60957	39043
	14	90032	09968	2	20	60050	39950
	15	89360	10640	2	22	59156	40844
	16	88692	11308	3	0	58275	41725
	17	88029	11971	3	3	56978	43022
	18	87372	12628	3	6	55711	44289
	19	86719	13281	3	9	54471	45529

Time.				Time.			
Days.	Hours.	A.	B.	Days.	Hours.	A.	B.
	20	86071	13929	3	12	53259	46741
	21	85428	14572	3	15	52074	47926
	22	84789	15211	3	18	50916	49084
	23	84156	15844	3	21	49783	50217
1	0	83527	16473	4	0	48675	51325
1	1	82903	17097	4	3	47592	52408
1	2	82283	17717	4	6	46533	53467
1	3	81669	18331	4	9	45498	54502
1	4	81058	18942	4	12	44486	55514
1	5	80453	19547	4	15	43496	56504
1	6	79852	20148	4	18	42528	57472
1	7	79255	20745	4	21	41582	58418
1	8	78663	21337	5	0	40657	59343
1	9	78075	21925	5	4	39455	60545
1	10	77492	22508	5	8	38289	61711
1	11	76913	23087	5	12	37158	62842
1	12	76338	23662	6	16	36059	63941
1	13	75768	24232	5	20	34994	65006
1	14	75201	24799	6	0	33960	66040
1	15	74639	25361	6	4	32956	67044
1	16	74082	25918	6	8	31982	68018
1	17	73528	26472	6	12	31037	68963
1	18	72979	27021	6	16	30119	69881
1	19	72434	27566	6	20	29229	70771
1	20	71892	28108	7	0	28365	71635
1	21	71355	28645	7	4	27527	72473
7	8	26714	73286	15	0	06721	93279
7	12	25924	74076	15	8	06329	93671
7	16	25158	74842	15	16	05961	94039
7	20	24414	75586	16	0	05613	94387
8	0	23693	76307	16	8	05287	94713
8	4	22993	77007	16	16	04979	95021
8	8	22313	77687	17	0	04689	95311
8	12	21654	78346	17	8	04416	95584
8	16	21014	78986	17	16	04159	95841
8	20	20393	79607	18	0	03916	96084
9	0	19790	80210	18	12	03579	96421
9	4	19205	80795	19	0	03271	96729
9	8	18637	81363	19	12	02990	97010
9	12	18087	81913	20	0	02732	97268
9	18	17291	82709	20	12	02497	97503
10	0	16530	83470	21	0	02282	97718
10	6	15803	84197	21	12	02086	97914
10	12	15107	84893	22	0	01906	98094
10	18	14442	85558	22	12	01742	98258
11	0	13807	86193	23	0	01592	98408
11	6	13199	86801	23	12	01455	98545
11	12	12619	87381	24	0	01330	98670
11	18	12063	87937	24	12	01216	98784
12	0	11533	88467	25	0	01111	98889
12	6	11025	88975	25	12	01015	98985
12	12	10540	89460	26	0	00928	99072
12	18	10076	89924	27	0	00775	99225
13	0	09633	90367	28	0	00647	99353
13	8	09072	90928	29	0	00541	99459
13	16	08543	91457	30	0	00452	99548
14	0	08046	91954	40	0	00074	99926
14	8	07577	92423	50	0	00012	99988
14	16	07136	92864				

A = fraction of emanation remaining after time t.

B = fraction of equilibrium amount of emanation formed in t days in a radium preparation initially free from emanation.

From this table Viol compiled Table VI which shows the total amount of emanation in millicuries from 1 gram of radium available in one month.

TABLE VI.—ACTIVITY OF RADIUM EMANATION PREPARATIONS ACCUMULATING IN THIRTY-ONE DAYS FROM ONE GRAM OF RADIUM ELEMENT IN SOLUTION. (After Viol.)

Age of emanation preparation in days.	Gamma ray activity in millicuries.
0	164.0
1	137.0
2	114.4
3	95.5
4	79.8
5	66.7
6	55.7
7	46.5
8	38.9
9	32.5
10	27.1
11	22.6
12	18.9
13	15.8
14	13.2
15	11.0
16	9.2
17	7.7
18	6.4
19	5.4
20	4.5
21	3.7
22	3.1
23	2.6
24	2.2
25	1.8
26	1.5
27	1.3
28	1.1
29	0.9
30	0.7
Total	991.8

From Table V it is evident that in twenty-four hours there accumulates 16.4 per cent. of the equilibrium amount of emanation. From Table VI we see that the theoretical daily yield of emanation from 1 gram of radium in solution is 164 millicuries. With modern apparatus, allowing for loss by leakage, breakage, etc., it is possible to obtain from 85 to 95 per cent. of this theoretical amount. Roughly this is about 150 millicuries per day. This may be divided into 5 tubes of 30 millicuries each. At the end of a month one will have 150 tubes of varying strength. The tubes that were collected on the first day will contain about 15 millicuries on the fourth day and so on until the thirtieth day when the strength will have dropped to less than 0.5 per cent. of its maximum activity. A tube on the fifteenth day will contain about 2 millicuries. In practice it is customary to use the

bes until they have dropped to 5 and even to 2 millicuries. Intense diation may be obtained by large quantities of emanation in a single ibe or by combining a large number of weak tubes. It will be seen Table VI) that the number of theoretical millicuries on hand at the nd of a month equals in activity that of a gram of radium. In ractice one usually has, with a gram of radium as a working basis, etween 800 and 900 millicuries available for use.

Measurement of Emanation.—While the details of measuring methods ary in different laboratories the fundamental principles are always he same. The measurement of quantity of radium or its products is based upon the electrical effects of the radiations emitted therefrom. It will be recalled that these radiations are capable of ionizing a gas and such a gas, previously a poor conductor of electricity, becomes a good conductor. If the ionized gas is between two metal plates or electrodes in a suitably constructed ionization chamber and these electrodes are at a difference of potential there will be a flow of current through the ionized gas, from one electrode to the other, the magnitude of which may be measured by electrical instruments (galvanometer, electrometer). If proper precautions are taken the magnitude of the current will depend upon the degree of ionization and this is turn will vary with the amount and kind of radiation entering the chamber. The magnitude of the current produced by an unknown quantity of emanation as compared to that produced by a known amount allows calculation of the unknown amount of emanation.

The electroscope is frequently used for quantitative estimation. A common method is to have an ionization chamber consisting of an insulated box of aluminium with windows, front and back. In this chamber are the two electrodes upon one of which there is attached a gold leaf. An electric light in the rear window illuminates the interior of the chamber and a shadow of the electrode and attached gold leaf is projected through the front window and falls upon a ground-glass plate at a definite distance from the instrument. At the proper distance from the rear of the apparatus there is a receptacle for the emanation tube. Between the receptacle and the chamber there is a plate of thick lead through which the radiation must pass to reach the ionization chamber (only gamma rays are used when estimating quantities of emanation in millicuries). The electrodes are given an electrical charge. The gold leaf projects outward in its attempt to reach the electrode of opposite polarity. The emanation tube is placed in the receptacle and the gold leaf drops. The gas (air at atmospheric pressure and normal temperature) in the ionization chamber has become ionized, the negative ions are attracted to the positive electrode and the positive ions to the negative pole. The charges being thus neutralized the gold leaf drops. The rate of motion of the leaf over a given scale is a measure of the ionization produced by the radiation in the ionization chamber. When such rates of motion are attained for known and unknown amounts of emanation their ratio

can be readily obtained and the unknown can be calculated in terms of the known.

Measurement by ionization is exceedingly technical and subject to many errors. If properly done, however, it is the most sensitive and accurate method we have for estimating radioactivity. Such work must be done only by physicists and highly trained technicians.

Emanation Unit.—The unit of emanation is the curie (in honor of M. and Mme. Curie) which may be defined as the amount of emanation in equilibrium with one gram of radium element. In practical work where very small amounts of emanation are employed the millicurie ($\frac{1}{1000}$ curie) is the standard unit of quantity. A millicurie of emanation in radioactive intensity is the same as a milligram of radium element. In the case of radioactive waters where the quantity of emanation is exceedingly minute Mache has proposed that, if the saturation current produced by the emanation from 1 liter of water amounts to 1 electrostatic unit of electricity per second in a standardized apparatus, the quantity of emanation present shall be called 1000 units. One millicurie is the equivalent of 2.7 million mache units (Knox). The mache unit is now obsolete.

Emanation Therapy.—The field of radium therapy is now a very large one. Radium will never replace roentgen rays as a therapeutic agent and the latter will not prevent radium from increasing in value in the field of medicine. They both have their advantages and limitations. There is room for both. There is need for both.

To cover the field of radium therapy, to treat cancer properly, to apply radium efficiently to all the affections that are amenable to this remarkable element, requires a great deal of experience and knowledge, a large amount of radium and an equipment that is initially expensive and that is costly to maintain. Such work is, of course, beyond the possibility of the ordinary physician and even the majority of specialists.

Radium therapy on an extensive scale is limited to highly specialized physicians who confine themselves to this work alone or who combine roentgen therapy and radium therapy as a vocation. Radium therapy, like roentgen therapy is not and will never be entirely limited to pure specialists. Specialists in various branches of medical practice and many general practitioners of medicine, especially those in small centers, will find use for these agents. And even with an exceedingly modest outfit, such physicians may accomplish a great deal of good and will avoid doing harm if they thoroughly understand the essential features of the work and the limitations of a small amount of radium.

Many readers of this book will wonder why so much space is devoted to details which apparently concern only the pure radiologist and which are seemingly of most interest to those who contemplate using these agents for the treatment of deep-seated affections, when the book is written mainly for those who do only the lighter and superficial work. The answer is simple. In the first place no physician should employ

either one of these agents unless he has a thorough and very general knowledge of their physics, therapeutics, biology, etc. In the second place, the problems that confront the operator, both in superficial and deep work, are very much the same. These problems are discussed in various parts of this book and need not be enumerated here. Suffice it to say that one cannot apply radium to superficial affections intelligently and efficiently without understanding the problems of deep therapy. As applied to disease the word superficial means nothing excepting in a relative sense. A superficial epithelioma may extend to a depth of five or more centimeters and the pathological tissue in many cutaneous affections attains a thickness of several centimeters.

Because a physician does not intend to use emanation is no reason why he should not understand why and how it is employed.

Why is emanation used instead of radium element? There are several reasons, but the chief reason is expressed by the words flexibility and versatility. The glass emanation tubes are exceedingly small, about ½ mm. in outside diameter, from 12 to 30 mm. in length and contain from 40 to 60 millicuries of emanation; a tube no greater in diameter than a hypodermic needle. One or two hundred millicuries of emanation or even a greater amount can be placed in a capillary tube that can be inserted into a fair sized hypodermic needle. Failla has forced 200 millicuries into a capillary tube 3 mm. in diameter and 2 cm. in length. Kelly has used a sphere, 3 mm. in diameter, containing 700 millicuries of emanation. This provides a very intense source of radiation no larger than the head of a pin. Thirty milligrams of radium element in the form of the compact, insoluble sulphate, will occupy a tube having a diameter of 3 mm. or more and a length of 2 or 3 cm. All this means that it is possible with emanation to obtain a minute source of intense radiation. When treating irregular lesions or lesions in inaccessible locations, lack of weight and bulk is of the utmost importance. If it is so desired an even more intense and minute source of radiation can be had by resorting to the active deposit of quick change.

Radium element, for practical work, is supplied as applicators of various sizes and shapes. The size, shape and strength of these applicators are fixed and cannot be changed at will to suit the requirements of the moment. It is true that a gram of radium may be divided into, say, 20 tubular applicators of 50 mg. each. Such tubes laid side by side on adhesive plaster would then form a flat applicator with a plane radiating surface. The individual tubes, singly or in combination, can be used in cavities or inserted into growths, for the treatment of lesions in inaccessible locations, etc. Half or a third of the radium might be sealed in needles for insertion into growths. But these applicators would be more bulky than those made from emanation tubes. The latter can be used in all sorts of ways. They can be placed in needles. The same tubes can then be used to form other applicators of any conceivable size or shape. It is customary to make

a mold or cast of the lesion, whether such lesion is on the surface or in a cavity, with dental compound. The tiny emanation tubes are then placed in all the irregularities of the mold thus making a plane radiating surface for an irregular or an inaccessible lesion. The mold is put in place and allowed to remain until the treatment is completed. The flexibility of the emanation method consists then in the fact that the size, shape and strength of an applicator can be changed at will in order to meet quickly the requirements of the moment.

Another important advantage in emanation therapy is the fact that the element is not handled. There is no danger of loss by accident and fire and very little from theft.

The disadvantages of emanation therapy are matters of time and expense. At least two or three hundred milligrams of radium element are necessary. While this will suffice as a modest beginning it is not economical because the initial and maintaining costs of the emanation equipment for this amount of element is almost as great as that required for a gram or two of radium. In practical work it is inadvisable to attempt emanation therapy with less than a gram of radium. Some private laboratories and hospitals possess several grams of the element. The usual market value of radium element is $125.00 per milligram. It is necessary to have a trained physicist and several trained technicians and assistants, and a complete equipment consisting of apparatus, instruments, floor space, etc. It will, of course, occupy the entire time of the radiologist to supervise such work. It is obvious, therefore, that emanation therapy must be left to hospitals, radium institutions and to private laboratories where the radiologist is able to obtain and operate the necessary amount of radium and equipment.

A radiologist who employs radium element escapes the expense of maintaining an emanation laboratory but he is handicapped by the lack of flexibility. He fails to obtain all that can be obtained in the way of therapeutic results.

Another disadvantage of emanation therapy is the fact that the strength of the emanation tube is constantly decreasing. This, however, does not bother the physicist or the trained technician. He can calculate, mathematically, and accurately, the exact amount of emanation in each one of his tubes at any time. The emanation tubes are never left on the patient more than a few hours and the decrease in strength during such exposure is almost negligible. Old tubes (two and three weeks old) are useful, as many such tubes placed in an applicator produce an intense source of radiation.

Emanation Applicators.—The preceding pages give the student a fair idea of how emanation is applied in the treatment of disease. It now remains to describe the actual construction of an applicator. There are no standardized applicators. Each radiologist has his own methods of making and using such appliances that seem best suited to his work. Janeway describes five different types of emanation applicators used by him and his associates at the Memorial Hospital in

New York. These applicators are ingenious, useful, and answer the demands of practical work. The following description of the applicators is taken practically verbatim from Janeway's writings:

1. The simple emanation tubes. These are $\frac{3}{8}$ to $\frac{1}{2}$ inch long and less than $\frac{1}{2}$ mm. in diameter. They may be inserted into the tissue, or laid upon it, or may be sealed into long aspirating needles (Fig. 51, A) which can then be inserted into the tissue.

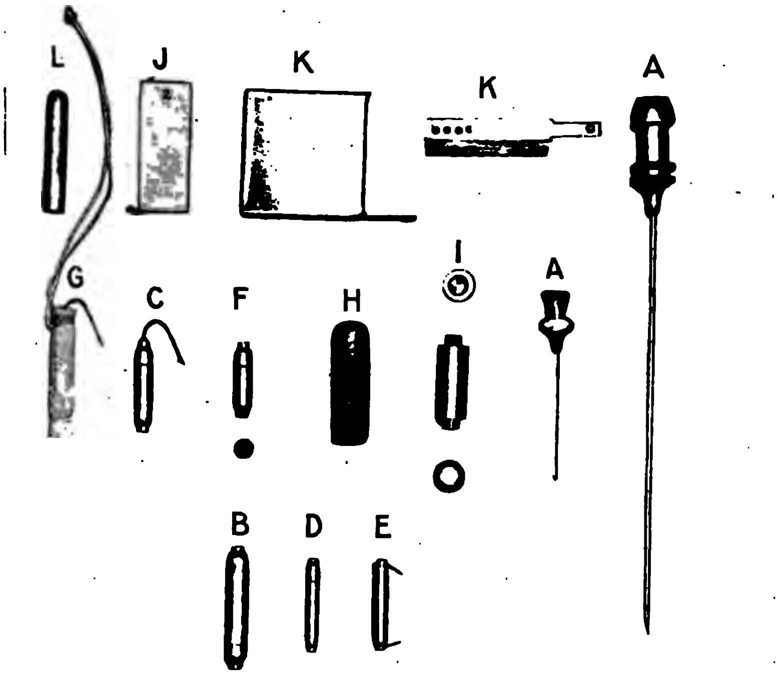


Fig. 51. —Showing various forms of emanation tubes and silver plaques described in text. (Janeway.)

2. Tubes of 0.25 mm. of aluminium or 0.1 to 0.5 mm. of German silver for light filtration and for protection of the emanation tubes.

3. For central strong application heavier filtration is as a rule desirable and for this purpose, as well as for surface application to mucous membranes, the platinum-iridium tubes (Fig. 51, B, C, D, E, F, G) have been constructed. The tubes are closed by two little caps which screw over the ends (Fig. 51, F). Each cap contains a threaded socket upon its distal end, into which may be screwed the base of the hook, C. This hook is of small size and contains a very fine barb. When the hook is screwed into the end of a tube, the tube

may be hooked upon almost any ulcer or mucous surface and can be relied upon to retain its position. This method has given successful results in the treatment of lesions of the tonsils, epiglottis and back of the tongue.

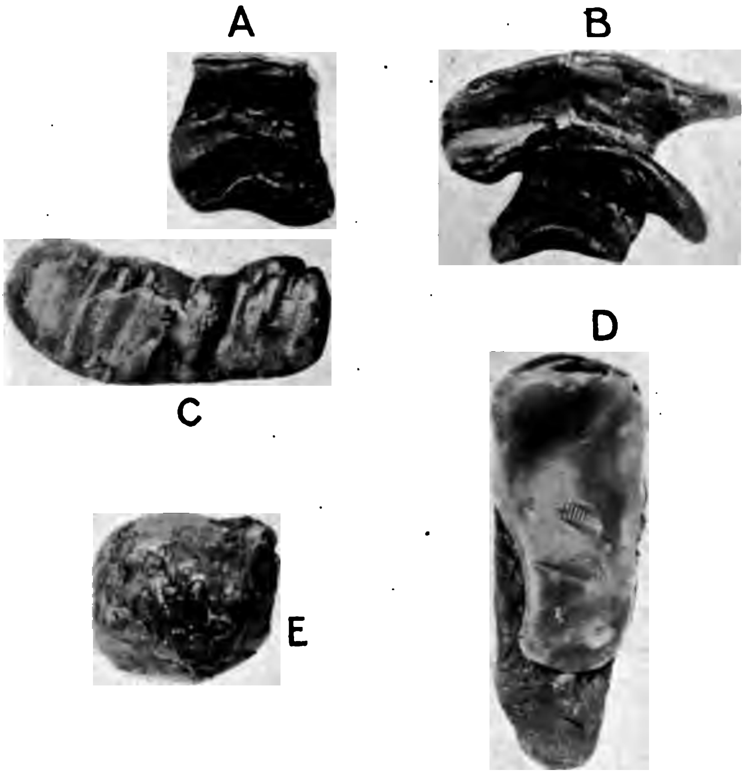


FIG. 52. —Applicators made of dental compound. A, B and E, applicators made to fit over the lower lip, showing the indentations made in a portion of the applicator which fits over the teeth, thereby affording stability when in place. D, similar applicator made for fitting into the vagina. The facing surface shows the tubes covered with a layer of paraffin 1 mm. thick. C, similar applicator made for covering a superficial lesion of the skin. (Janeway.)

More recently Janeway and his associates have made molds of intra-oral and even intravaginal and intrarectal tumors, the molds being made with dental modeling compounds. Within the areas on these molds corresponding to the tumors, properly filtered emanation tubes are enbedded. Such applicators are very successful and are capable of the widest application (Figs. 52 and 53).

Platinum tubes or containers are made in three sizes: Tube 1, with a bore of 2 mm. and a wall 1½ mm. in diameter (Fig. 51, B), giving

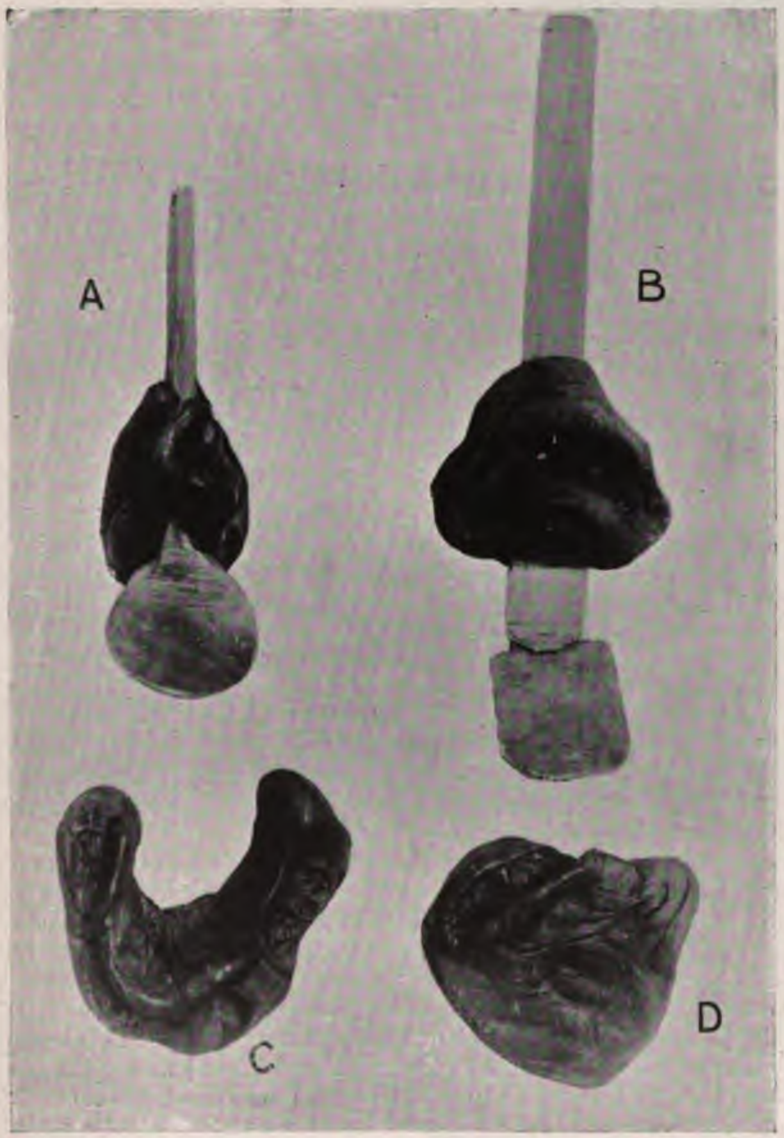


Fig. 53.—Applicators of dental compound designed for treating lesions of the back of the tongue (B), side of the tongue (C and D), and tonsil (A). (Janeway.)

approximately the filtration of 3 mm. of lead. Platinum is used because it is less bulky than lead. The drilled central portion is 2 cm.

long. A good many weak emanation tubes may be inserted within tubes of this size. They are serviceable for the administration of practically homogeneous gamma radiation.

Tube 2: A tube with a bore of 2 mm. and a wall of 1 mm. in thickness (Fig. 51, C and F). Its drilled central portion is 1¼ cm. This tube also can be filled with many emanation tubes and gives a very strong dose. The filtration is equivalent to 2 mm. of lead. The rays are a little less "hard" than are those from tube 1, but the tube is smaller and lighter and is better adapted for many buccal lesions.

Tube 3: The bore of this tube is 1 mm. and the walls are 1 mm. thick (Fig. 51, D and E). Its drilled central portion is 1¼ cm. long. The filtration is the same as with tube 2, but it will accommodate only one emanation tube. If, therefore, this container is to be the source of intense radiation it must hold a new emanation tube. However, weak emanation tubes may be used and the difference in intensity made up by increasing exposure time, or several containers may be employed. Inasmuch as these containers are smaller than the others, several of them may be placed on the surface of a lesion thereby obtaining a more uniform distribution of intensity.

This is, according to Janeway, the most useful of all the containers used at the Memorial Hospital. By placing the tubes side by side, as already mentioned, a plane radiating surface is obtained. Used in this manner they form the most serviceable applicators for deep penetration in the treatment of mucous membrane lesions. The small size of these containers makes it possible to insert them within all the crevices and irregularities of ulcerated lesions so that a plane surface can be had for a lesion of almost any shape.

Where it is desirable to have an intense radiation from a single source, as in the cervix, crateriform ulcers, etc., lead containers may be employed. The lead containers are similar to the platinum containers in construction excepting that the caps do not possess sockets for the attachment of the hooks (Fig. 51, H and I).

4. For external use on flat surfaces square plaques of lead (Fig. 54, A, B, C, D, E) and silver (Fig. 51, J and K) are used. The plaques are 6 or 8 mm. thick and are drilled with parallel holes 2 mm. in diameter (Fig. 54, C). A thickness of 2 mm. and 3 mm. of lead therefore exists between the holes and the surface of the plaque. The ends of the holes, at the end of the plaque, are closed by end-pieces of 2 or 3 mm. of lead (Fig. 54, B) and the plaque and the end-piece are held together by a little box of aluminium the walls of which are ½ mm. thick (Fig. 54, A, B, C). Emanation tubes are placed in the parallel holes and as many plaques as needed are placed together to cover a large surface (Fig. 54, F). These plaques are 1 inch square, ½ inch square and ½ by 1 inch. By means of them the emanation may be spread out practically uniformly over a flat surface. The aluminium cuts out the secondary rays from the lead but in addition, it is advisable to separate the plaques from the surface by a few layers of gauze.

5. The fifth form of applicator described by Janeway is made by either combining the lead plaques (Fig. 54, F) or filling little lead trays sunk into a small board 10 x 12 cm. (Fig. 55). Because increased distance tends to equalize the distribution of radiation throughout a greater depth, applicators that separate the source of radiation from the lesion or from the surface by a few centimeters are preferable when treating lesions situated below the surface. Figs. 55 and 56 show applicators that answer this purpose.

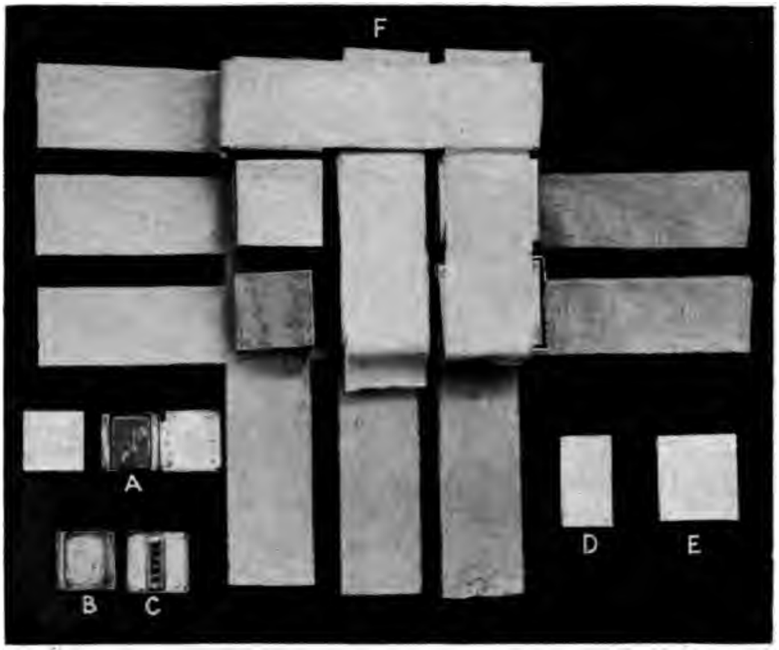


FIG. 54.—Showing the construction of the radium pack by which many emanation tubes are spread out over a surface 9 x 12 cm., and enclosed in separate plaques of lead 2 mm. in thickness around centrally drilled holes containing the tubes. (Janeway.)

Dosage.—The question of dosage in radium therapy is complicated by many factors. There is as yet no standard method. The strength of emanation tubes and radium applicators is expressed in terms of millicuries of emanation or milligrams of radium element. Quantitative estimation is based on the electrical effects of ionization produced by gamma rays. The length of exposure will depend upon the strength of the applicator, its distance from the skin, the extent of treated surface and the character of radiation (beta or gamma). The character of radiation is governed by the filtering material and its thickness. The effect of filtration and distance will be discussed later in this chapter. Suffice it to say here that dosage is largely a matter of experience.

Failla has attempted to standardize a unit of intensity by means of ionization. This unit he calls a radion (from the roots of radiation and ionization). By means of plotted absorption, intensity and distance curves, it is possible to calculate intensity in terms of radions on the surface or at varying depths below the surface. The method is ingenious but it has not been given a thorough practical test.

Fig. 55.—An improved applicator for treating with heavily filtered emanation at a distance from the skin surface. The applicator consists of a board in which are sunk little lead trays of 2 mm. lead. Into these trays large numbers of old emanation tubes may be placed. The applicator measures 12 x 10 cm. and is much lighter than that made of the lead plaques, though not so light as the pack made of platinum tubes. It makes a convenient method of utilizing weak emanation tubes for a long period and yet contains *in toto* a large number of millicuries. (Janeway.)

Millicurie Hours.—This is an inaccurate way of expressing dosage. A millicurie hour is one millicurie of emanation applied for one hour or 60 millicuries applied for one minute, etc. In designating dosage in this manner it is necessary to state all the details of the treatment, otherwise a millicurie hour means very little. When radium element, instead of emanation, is employed the term milligram hour has been used. These terms were once popular but they are used very little now. Nevertheless, when associated with proper details they are capable of conveying considerable information. Hence, Janeway

referring to the applicators already described, finds that 60 millicurie hours per tube constitutes a safe dose when small areas of 1 to 5 sq. cm.

Fig. 56.—Applicator formed with wooden blocks. A, a form of applicator made of wood 2 cm. thick, through which a hole one inch in diameter is drilled. The emanation tubes are shown adherent to the adhesive plaster, covering one end of this hole. The open end of the applicator is applied to the surface of the lesions. In this form of applicator slightly filtered radium is used and it forms a method of treating superficial lesions at a distance from the lesion with soft gamma and beta rays. B, a form of applicator constructed of several plugs of wood which are drilled to receive 1 mm. platinum tubes. These tubes may be filled with strong emanation tubes and the applicator forms a method of treating lesions with evenly distributed radium emanation, strongly filtered, and yet contained in a very light applicator which may, therefore, be placed at considerable distance without much discomfort or inconvenience to the patient. (Janeway.)

are irradiated, the filtration being 1 mm. of platinum and a thin piece of rubber, the applicator being close to the skin. A lead container 2 mm. thick will allow a dose of 100 millicurie hours per tube. If the filter is 0.5 mm. of German silver the dose will be 30 millicurie hours per tube. These doses are given to circumscribed, superficial lesions of various thicknesses. When large surfaces are covered the total dose is usually 30 millicurie hours. When the 2 mm. lead plaques are used it is safe to give a total dose of 300 millicurie hours per square centimeter.

For deep penetration a total of 10,000 to 12,500 millicurie hours may be applied per 100 sq. cm., filtered through 2 mm. of lead and at a distance of 6 cm. A dose as high as 18,000 millicurie hours at a distance of 10 cm. is sometimes used. A centrally placed strong applicator, filtered through tumor tissue, will allow a dose of from 500 to 12,000 millicurie hours.

RADIUM ELEMENT APPLICATORS.

Permanent radium applicators are supplied in various forms—needles, small glass tubes and flat applicators. The content is a radium salt, usually the sulphate, but the strength is given in milligrams of radium element. In former years it was customary to speak of the strength of a radium applicator in terms of activity, the activity being determined by ionization and compared with uranium as a unit. Radium element, in this respect, was found to be 2,000,000 times more active than uranium. The amount of radium salt and its activity was found to be a poor way of designating the strength of an applicator.

When giving the strength of a radium applicator one should give the number of milligrams of radium element contained therein, not the amount of radium salt.

Manufacturers of radium applicators certify to the contents (milligrams of radium element) and supply information relative to time of equilibrium, etc. In addition it is advisable to have the applicator standardized by the United States Bureau of Standards. The National Bureau will, at a very nominal expense, certify to the equivalent radium content.

Stratton, of the National Bureau, gives the following information for those purchasing radium:

"In the routine testing of hermetically sealed radium preparations, the ionization produced in a given ionization chamber by the penetrating gamma radiation proceeding from the preparation is compared with that produced under the same conditions by the similar radiation from a standard containing a known amount of radium. Mesothorium preparations also emit a penetrating gamma radiation, and consequently by a single comparison with the radium standard in the manner just indicated there is no means for distinguishing such a preparation from one containing only radium and its derivatives.

"It is for this reason that the usual radium certificate issued by the National Bureau of Standards contains no statement concerning the actual amount of radium contained in the preparation, but merely a statement of its equivalent radium content. The primary object of the measurement of such preparations by the Bureau is to insure the purchaser against any serious error in the radioactive measurement of the preparation.

FIG. 57.—Case containing flat radium applicator and handles.

"The carnotites, from which the domestic radium is produced, are known to contain only a negligible amount of mesothorium. Tests made on radium produced from such ore gave no evidence of the presence of mesothorium, and were such as to indicate that the mesothorium present cannot exceed 0.2 per cent. of the radium content of the material. Consequently, it is quite safe to assume that the radium produced from these deposits will be practically free from mesothorium unless the latter product is deliberately added. This is a matter over which the producer has control and concerning which he can speak with confidence. It is customary for the domestic producers of radium

to guarantee that their product is practically free from mesothorium, and such a guarantee might well be requested by the purchaser.

"Although the examination of a hermetically sealed radium preparation for the presence of mesothorium forms no part of the routine measurement of such materials by the Bureau, such examination will be made when requested under conditions that justify the work. These examinations are laborious, require the opening of the preparation and the removal of some of the salt, and involve the risk of a considerable loss of material. As in the case of all tests made by the Bureau, the applicant must furnish the material used, assume the risk of loss, and pay a fee commensurate with the labor involved.

"On the other hand, even without this examination the purchaser is not left entirely to the mercy of unscrupulous dealers. Repeated gamma ray comparison, using radiations filtered through different thicknesses of lead, will in general furnish data from which it can be determined whether much of the radiation from the preparation is due to mesothorium. Such tests on sealed specimens are deliberately made from time to time, and similar but less complete data are incidentally obtained from many specimens in the routine course of the testing. In no case has such test revealed to us the presence of mesothorium in any preparation that has been submitted to this Bureau as one free from mesothorium; but few imported preparations have been so tested.

"Another check on the possible presence of a significant amount of mesothorium in a radium preparation is afforded by its remeasurement. If the preparation contains a significant amount of mesothorium, then a second measurement made several months after the first will reveal:

"1. A growth in the intensity of its radiation if all radiothorium had been removed from the material shortly before the first measurement.

"2. Little or no growth if the radiothorium was last removed two or three years before.

"3. A decrease of the radiation if the radiothorium had not been removed for over three years.

"It is evident that unless the two measurements are very especially related to the age of the contained mesothorium, they will reveal its presence.

"In the course of its work, the Bureau has to its knowledge remeasured forty-seven radium preparations after intervals varying from two weeks to four years. Preparations from three domestic producers are included in the list. Some of these preparations are resubmitted by their producers, others by their purchasers. For fifteen of the preparations, the interval between these measurements exceeded six months. In no case did the difference between the two measurements exceed the sum of the allowable uncertainties of the two measurements. Excepting a single case in which the initial determination was known to have an unusually low precision, a difference as great as 0.9 per cent. was found in only one instance. The average difference was 0.34 per

cent. The second measurement usually, but not always, exceeded the first. This probably results from the fact that in many cases the radium had not fully attained its equilibrium at the time of the first measurement. Even thirty days after the radium preparation is sealed, it is 0.45 per cent. short of its maximum gamma radiation.

"Whence it is seen that as yet we have found no indication that any hermetically sealed preparation offered by a domestic producer as a radium preparation contains an appreciable amount of mesothorium. Very few such specimens offered by small dealers, jobbers or importers of radioactive material have been submitted to the Bureau. Consequently we are at present not prepared to express an opinion concerning the material obtained from such sources."

Flat Applicators.—This is the form of applicator used mostly by dermatologists or by radiologists when treating cutaneous affections. Such applicators range in size from a dime or smaller to a silver dollar or larger. They vary in shape from round, oval and oblong to square. They are usually flat, but concave or convex applicators can be obtained. There are no flexible radium applicators, excepting the toile type and those made of radium tubes. The applicator is usually composed of silver, sometimes backed with lead, on which is placed an emulsion of a radium salt in a special varnish, enamel, or other suitable substance. Fixing is obtained by drying or by baking. Handles, straight and curved, and of various lengths, are supplied. These may be screwed into a threaded receptacle situated on the back or on one edge of the applicator.

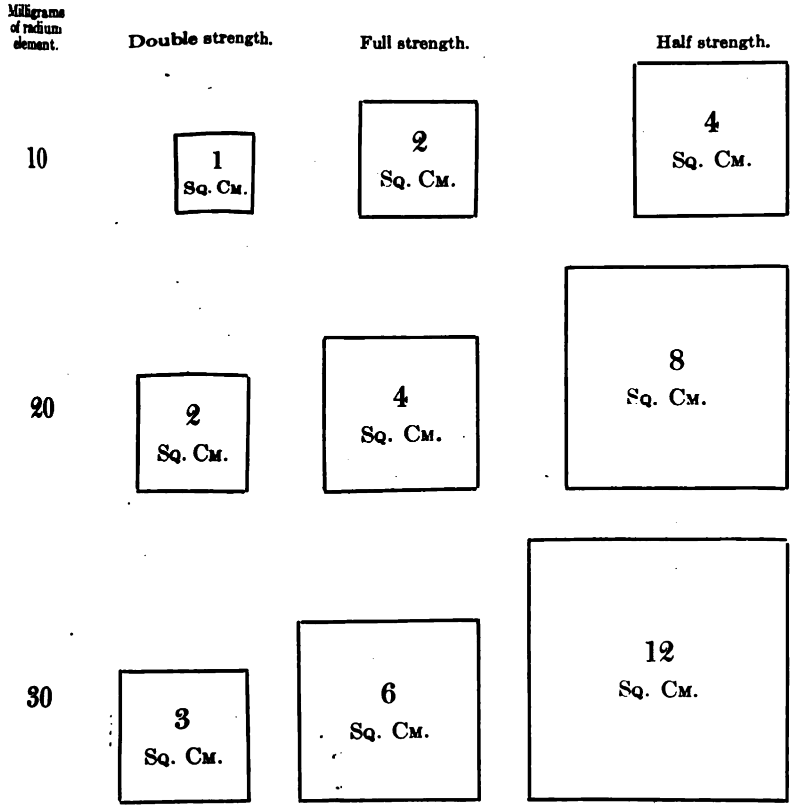
The varnish prevents the passage of the alpha rays excepting those that have their origin close to the surface. The varnish absorbs, also, a certain amount of the very "soft" beta rays. With these exceptions such an applicator is unfiltered. An unfiltered applicator allows the utilization of all but the extremely "soft" beta rays but such applicators are not popular because the varnish undergoes a chemical change in a few years, becomes brittle and pieces break off. Considerable radium has been lost in this manner. Even new varnish applicators may be injured by rough handling and by attempts at sterilization. All types of applicators should be watched carefully for deterioration of the varnish or glass and it is wise to return them to the manufacturers every few years for testing and, if necessary, to be made over.

Viol describes a glazed flat applicator. The radium salt is mixed with lead-free glass (fused silica or glaze) and fused on to a silver plate. By employing very little glaze it is claimed that there is no more filtration than with varnish and that such applicators will last a much longer time and that they will not be injured when dropped on a hard floor.

Varnish applicators are often made with a covering of mica, or some secret material, or a very thin layer of aluminium or silver foil (0.1 mm.) This prevents possible loss of radium but it also filters out a certain amount of the beta rays. One-tenth millimeter of silver will prevent the passage of most of the "soft" beta rays and it will absorb about

activity of varnished applicators varies with applicators from different dealers and in some instances even in the case of supposedly identical applicators from the same dealer. This is partly due, perhaps, to a slight difference in radium element content, but it is probably due mostly to the varying thickness of the varnish, methods of making and drying the suspension, different kinds of varnish, etc. In time it is possible that a commission composed of therapeutists, physicists and manufacturers of applicators will determine the best type of flat applicator (varnish, glaze, etc.), and standardize its manufacture.

TABLE VII.—FLAT RADIUM APPLICATORS—ACTUAL SIZE.



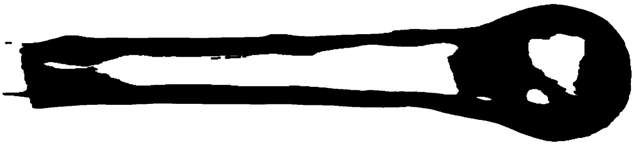
Milligrams of radium element.	Double strength.	Full strength.	Half strength.
10	1 Sq. Cm.	2 Sq. Cm.	4 Sq. Cm.
20	2 Sq. Cm.	4 Sq. Cm.	8 Sq. Cm.
30	3 Sq. Cm.	6 Sq. Cm.	12 Sq. Cm.

Toile Applicators.—A toile applicator consists of heavy gauze, linen, silk, cloth or similar substance on which is coated the radium varnish. Such applicators are flexible and permit the use of very "soft" beta rays and even the alpha rays. They do not last long and one is likely to lose considerable radium unless care is exercised. They are not popular.

Radium Tubes.—Tubular applicators consist of tubes composed of thin soda-glass having a diameter of 2 or 3 mm. The length will depend upon the amount of radium salt contained therein. The in-

FIG. 59.—Radium tubular applicator in heavy lead container and leather box.

FIG. 60.—Showing the glass radium tubular applicator, the silver container, the brass container and the heavy lead holder.



[illegible] tail. [illegible]
[illegible] purpose of filtration [illegible]

containers supplied with eyelets to which a thread may be fastened. Ten, twenty-five, fifty and one hundred milligram tubes are the ones commonly used.

Needle Applicators.—Radium needles vary in size from heavy sewing needles to aspirating needles depending upon the amount of radium contained therein. The actual size of a needle containing 12½ mg. of radium element is shown in Fig. 65. It has an iridium-platinum point which does not become blunt with use. The needle itself is usually composed of thin silver or platinum. A metal container, holding two or three of these needles (Fig. 66) may be used as a filtered tubular applicator. The needles possess an eyelet to which a thread may be fastened.

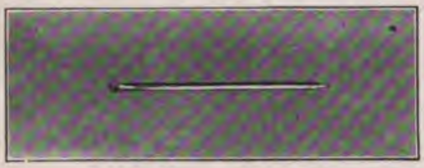


Fig. 65.—Radium needle applicator (actual size).

Fig. 66.—Three radium needle applicators in metal container, the whole forming a tubular applicator.

Filtration.—The use of a suitable filter is of the utmost importance in radium therapy. Many flat applicators, as we have seen, contain or are covered with material that will absorb part or all of the "soft" beta rays and varying percentages of the "hard" beta rays. Such filtering material will also absorb the "soft" gamma rays. The walls of a glass radium tube will allow only the more penetrating of the beta rays to pass. The same is true of the thin-walled needles when composed of metals of light atomic weight.

Unfiltered varnished and glazed or enameled surfaced applicators are suitable for the treatment of cutaneous conditions where the skin is only slightly thickened. It must be borne in mind that a large percentage of the output of such an applicator consists of "soft" beta rays. These rays are exceedingly active biologically and they are absorbed by a few millimeters of epithelial tissue. If the epidermis is thickened or the disease is in the derma, then a thin filter is indicated. If a filter is not used then the epidermis by absorbing the "soft" beta rays will receive a lethal dose before the more deeply seated pathological tissue can receive enough "hard" beta rays to be favorably influenced.

When unfiltered applicators are placed in direct contact with the skin they should be covered with thin rubber (rubber dam used by dentists) or oiled silk in order to protect them against secretions and exudations.

The absorption of beta rays (omitting the "soft" rays) follows

closely an exponential law. That is, an equal thickness of the same material will absorb the same fraction of the incident radiation. Thus, if initial intensity is cut to ½ by 0.40 mm. of aluminium, it will be reduced to ¼ by 0.80 mm. of aluminium and so on. It would probably require about 5 mm. or more of aluminium to stop most of the very penetrating beta rays. One centimeter of epithelial tissue will reduce the initial intensity of beta rays of high velocity to about 6 per cent., by absorption alone. There is a further loss of intensity by distance, which varies somewhat with the size of the applicator but which may for practical purposes be assumed to vary inversely as the square of the distance. These facts must be taken into consideration when treating superficial conditions with surface applicators. By eliminating all but the more penetrating beta particles by suitable filtration it is possible to obtain intense beta ray effects (by sufficiently long exposures) to a depth of one or two centimeters. The thickness of the skin in most cutaneous affections is within one centimeter but many of the granulomata and new growths (epithelioma, mycosis fungoides, verruca, keloid, etc.), attain a thickness of several centimeters. In such instances it would be unwise to utilize the beta rays unless there was an opportunity to cross-fire or to insert radium needles into the tissue.

If the condition to be treated is more than one or two centimeters below the surface or if the disease extends to this depth it is preferable to omit the beta rays entirely. The object in such instances is to obtain suitable intensity in the deepest part of the lesion without undue injury to the more superficial tissue. In other words, to obtain a fairly uniform distribution of radiation throughout the entire diseased area. The use of a heavy filter is one way of obtaining this object.

After the beta rays and "soft" gamma rays have been eliminated the absorption of gamma rays obeys an exponential law. After passing through 2 or 3 mm. of lead or its filtration equivalent, gamma rays are almost homogeneous. It will then require in the neighborhood of 8 mm. of lead to cut such radiation to half value. This radiation in passing through human tissue obeys the same law. It is obvious, therefore, that if all the beta rays and easily absorbed gamma rays are omitted, there is a much better opportunity of equalizing intensity throughout several centimeters of tissue. This does not take into consideration loss of intensity by distance. It is a very uneconomical method of treatment from the standpoint of wasted energy, but it is the best we can do until such time that a method is devised whereby the source of radiation can be distributed equally throughout the diseased region, allowing the utilization of the alpha, beta and gamma rays. As Failla suggests, this might be accomplished by the injection of minute insoluble particles containing active deposit.

The following table shows the thickness in millimeters of various

materials required to absorb approximately 50 and 99 per cent. of beta radiation from an unscreened applicator.

TABLE VIII.

Material.	Density.	50 per cent.	99 per cent.
Water	100	1.0	8.50
Gum rubber	0.91- 0.93	1.0	8.50
Bone	1.70- 2.0	0.60	5.00
Glass (common)	2.40- 2.8	0.40	3.30
Aluminium	2.50- 2.68	0.40	3.20
Steel	7.83	0.14	1.15
Brass	8.40	0.13	1.10
Nickel	8.82	0.13	1.10
Copper	8.85- 8.94	0.13	1.05
Silver	10.5	0.11	0.90
Lead	11.37	0.10	0.80
Mercury	13.55	0.07	0.67
Gold	19.26-19.55	0.06	0.50
Platinum	21.50	0.05	0.40

The exposure time will vary markedly with the amount of filtration. An unfiltered varnished or glazed applicator that will provoke an erythema as a result of an exposure (in contact with the skin) of five minutes will require something like an hour for an erythema if the radiation is passed through from ½ to 1 mm. of aluminium. Filtered with 2 or 3 mm. of lead such an applicator might be left on the skin for from eight to twelve hours. The increase in time is due mostly to absorption by the filtering material but it is partly caused by the fact that the interposition of a substance between the radiator and the skin increases the distance between the source of radiation and the skin. The increase in distance is at times quite a factor as, for instance, where 2 mm. of lead and several layers of wet gauze or a layer of chamois is used.

The author is often asked to describe a method of separating and using only one type of radiation. While this is an exceedingly elementary question it seems to be one that perplexes a great many workers of limited experience. Alpha rays, of course, can be discarded at once because almost anything, even the varnish in the applicator, will absorb them. The beta rays can be obtained unmixed with other types of radiation by means of magnetic deflection, but this is never done in practical work because there would be no advantage in so doing. In applying beta rays, gamma rays also pass into and through the tissues but the former are so much more numerous and so much more active and require such a comparatively short exposure, that the effect of the gamma rays is slight. It is not possible, in practical work, to separate the "soft" gamma from the "hard" beta rays. By heavy filtration all radiation is absorbed excepting the gamma rays of short wave length.

It makes little difference what filtering material is employed so long as the thickness of such material is sufficient for the desired effect. The absorption of radiation is roughly in proportion to the density of

the substance through which the radiation passes. Thus 0.05 mm. of platinum, 0.10 mm. of lead, 0.11 mm. of silver, 0.13 mm. of brass, 0.40 mm. of aluminium and 0.40 mm. of lead-free glass, all will absorb about the same quantity of beta radiation. There is one advantage in using a heavy metal as a filter—less bulk allows closer contact of applicator and skin. For instance, 0.05 mm. of platinum will allow the face of the applicator to be closer to the skin than will 0.40 mm. of aluminium, therefore the exposure will be longer in the case of aluminium than in the case of platinum. Thin material is advantageous when making very small applicators, such as needles, tubes, etc.

Absorption of Secondary Radiation.—The heavier metals give rise to secondary gamma and secondary beta rays when acted upon by primary gamma rays. Most of these secondary radiations are absorbed by superficial tissue so that their presence tends to defeat the object of filtration. A thin layer of a light metal such as aluminium gives rise to very few if any secondary rays, therefore it is customary to use a heavy metal (lead, platinum) for the purpose of filtration and a millimeter of aluminium, soda-glass, leather, chamois or several layers of wet gauze to remove most of the secondary rays.

The usual filtering material is lead when it is desired to employ only gamma rays. Lead gives rise to very "soft" secondary rays. These rays effect a superficial "burn" which is not very troublesome and which heals in a short time. It is this type of radiodermatitis that has led some radiologists to aver that gamma ray "burns" are not as injurious as are reactions caused by roentgen rays.

Standard Dosage for Permanent Applicators.—It is not possible to standardize radium dosage by radiometric methods as is done with the roentgen rays. Ionization is used to determine the strength of the applicators but until every applicator from every manufacturer is the same in all its details the ionization method cannot be used to standardize dosage. Until some uniform method of measurement and manufacture is worked out it is preferable for the radiologist to standardize his own applicators under varying conditions on his own person.

Standardization by Skin Effects.—Cover the surface of the unfiltered varnished or glazed applicator with a piece of lead foil 1 or 2 mm. thick, and a thin layer of aluminium through both of which a split-pea-sized hole is cut. Strap this to the flexor surface of the forearm firmly enough to bring the actual surface of the applicator in contact with the skin. For a full strength applicator make exposures of successive areas for one, two and three minutes. Wait two weeks for a possible erythema. If none develops proceed as before up to an exposure of six minutes. Assume that a five-minute exposure gives a faint but definite erythema. Five minutes, unfiltered, contact with skin, would be the erythema dose for this particular applicator. Inasmuch as the sensitiveness of the skin varies with age, location, etc., (see page 260), it is preferable to select fairly young skin and because of medico-legal possibilities it is better for the operator to experiment

on his own person. It is well to bear in mind, too, that the exposure will be a little less for the same effect if no lead is used for protection. The effect is always a little more marked when the radiation is applied to larger surfaces and besides, if the lead and aluminium are removed, the applicator may come in closer contact with the skin.

In the same manner the erythema dose is ascertained for flat applicators screened with various thicknesses of aluminium and lead or their equivalents in other metals, care being taken to absorb the secondary rays when the heavy metals are used. Tubular applicators and needles are tried out in the same way. The applicators should be tested singly and in combination, in contact with the skin and at varying distances from the skin. When attempting to determine the saturation dose for heavily filtered radium, caution must be exercised as here the effect is not only on the skin but on the deeper tissues. Janeway's system of dosage in emanation therapy, quoted in this chapter, will help the beginner if it is recalled that 1 milligram of radium element has about the same value as 1 millicurie of radium emanation if used under similar conditions. After the saturation dose has been determined the time of exposure may be divided for fractional doses. The use of animal skin for standardization will not do because of the enormous differences in sensitiveness between human skin and that of the lower animals.

Treatment of Deep-seated Lesions.—The treatment of very thick lesions, lesions under the skin and lesions at still greater depths, offers a problem in radium therapy that has not yet been entirely solved. The aim is to administer a dose sufficient for the desired effect at a certain depth without undue injury to the intervening tissue. There are three ways in which this result may be obtained to a certain degree—1, filtration; 2, distance; 3, cross-fire.

1. Filtration has been discussed already in this chapter. Suffice it to say here that the screening material should consist of from 1 to 3 mm. of lead or its filtration equivalent in some other metal. The lead should be covered with aluminium, glass, chamois or rubber in order to absorb the "soft" secondary rays.

2. The effect of distance is discussed on page 165 in connection with the roentgen rays. The same theory holds for radium. In some respects the distance factor is more important in radium therapy than in roentgen therapy. In the latter the source of radiation is always from a distance and, furthermore, it is from a small point. With radium, except when using very small tubular applicators, the source is not from a single point. Glazed and varnished applicators and flat applicators made of a number of radium or emanation tubes provide a plane surface of radiation. From a small source intensity varies inversely as the square of the distance. While this law is not strictly correct for a plane radiating surface, yet for practical purposes it may be said to hold true. A plane surface is composed of multiple minute sources of radiation and the total effect can be determined by the mathematical process of integration. Assuming, therefore, that the

inverse square law holds for any radium applicator, distance becomes an important factor when attempting to obtain equal intensity throughout several centimeters of tissue.

As an illustration let us assume a tumor 1 cm. thick situated 3 cm. under the skin. The radium applicator is placed at a distance of 6 cm. from the skin. The distance between the source of radiation and the lowermost layer of pathological tissue will be 10 cm. Bearing in mind the inverse square law, intensity at the skin compared with intensity at tumor is as 100 is to 36—approximately 3 times. Now place the applicator at a distance of 1 cm. from the skin. Intensity at skin compared with intensity at tumor is as 25 is to 1—25 times. This shows a marked increase in the relative amount of radiation received by the skin as compared with that received by the tumor. If the applicator is placed in contact with the skin or within 1 or 2 mm. of the skin, the amount of radiation received by the skin as compared to that received by the tumor will be very greatly increased.

The effect of absorption by air and by intervening tissue is omitted in this discussion of the effect of distance. This phase of the subject has been considered elsewhere in this chapter. With gamma rays of short wave length the loss by absorption in the air is negligible. The absorption by tissue is practically exponential and is not very great for a few centimeters. It requires something like 10 cm. of average human tissue to reduce heavily filtered gamma radiation to half intensity. The next 10 cm. would reduce intensity to 25 per cent. of the initial energy, etc. It should be obvious that the distance factor is of the utmost importance in treating lesions below the surface. It permits of a useful amount of radiation to reach a subcutaneous tumor without destroying or injuring the intervening tissues. Many types of cancer are four times more susceptible to irradiation than is norml human tissue. By suitable filtration and distance it is possible to obtain four times the biologic effect on a subcutaneous tumor than on the overlying tissue. Increasing the distance will, of course, increase the time of exposure. The increase in time will be roughly as the square of the distance. That is the exposure time will be four times greater at a distance of 2 cm. than at a distance of 1 cm. This is a small item when using emanation as the applicator can be increased sufficiently in strength to compensate for loss by distance. But for those who have only a few flat or tubular radium applicators the increase in exposure time associated with increased distance is an annoying handicap.

3. The subject of cross-fire is discussed in Chapter XIX. It is possible to utilize cross-fire oftener and to greater advantage in radium therapy than in roentgen therapy. Tumors that are elevated above the surface may be literally covered with tubular applicators. Lesions or tumors situated on or in the ear, lip, tongue, fingers, etc., may be surrounded with applicators. Cross-fire also includes the use of radium needles and the insertion of tubes at various points within a tumor.

Treatment of Flat Surfaces.—Flat applicators are most convenient when the surface to be treated is flat. If the lesion is smaller than the applicator the normal skin should be protected by means of lead foil. If the applicator is smaller than the lesion two or more applicators may be used at one time or one applicator can be made to cover the necessary territory by successive exposures to different parts of the lesion, care being taken to avoid overlapping. If the lesion is superficial, the flat permanent applicator may be applied in direct contact with the skin. If the disease extends to a considerable depth the applicator should be held at a distance of from one to six centimeters. Radium tubes and emanation tubes can be placed in parallel series on zinc plaster or in applicators such as those mentioned in an earlier part of this chapter. A plane radiating surface can thus be created. When using tubular applicators in this manner it is customary to leave a space of from ⅛ to ¼ inch between the tubes and to have the radiating surface at a little distance from the skin. This is for the purpose of obtaining a more uniform intensity at the skin surface and also a more uniform distribution of radiation throughout the pathological tissue. Finally, as already mentioned, it is possible to obtain flat applicators of the active deposit of quick change.

Treatment of Convex Surfaces.—Convex and irregular surfaces are difficult to treat unless one is well equipped with tubular applicators—emanation or radium element. Convex lesions of large dimensions may be treated by using flat applicators, such applicators being placed all over the tumor, preferably at a little distance from the surface. It is much easier, however, to use parallel series of tubes on zinc plaster. A still better method, especially if the lesion is very irregular, is to make a cast of the lesion with dental compound, place the tubes at proper intervals and depths in the cast and place the latter on the lesion. This method is particularly applicable to lesions situated in such cavities as the mouth, external auditory meatus, vagina, etc. Finally, radium needles may be inserted at proper distances throughout the tumor. An operator working with one or two tubes is at a disadvantage, but the surface can be covered by making successive exposures.

Treatment of Concave Surfaces.—Such surfaces are best treated with tubular applicators, preferably in connection with the dental compound. In the case of crateriform lesions one or more tubes may be inserted into the cavity, vertically. Flat radium applicators can be utilized if the lesion is a large one, but usually some form of tubular applicator (zinc plaster flexible applicator) is required.

It is impossible to give all the details relative to the treatment of lesions of various shapes and sizes. The requirements will differ with almost every case and will vary according to the equipment. The radiologist who uses emanation will have the least difficulty, and he who has a large amount of radium in tubular applicators will have less trouble than the radiologist who possesses a small amount of radium divided between three or four flat and tubular applicators. It is neces-

sary to use ingenuity and judgment and not attempt the impossible with inadequate equipment.

Intervals Between Treatments.—This subject is discussed in Chapter XIX in connection with roentgen therapy; there is very little to be added here. It seems to be the consensus of opinion among radium therapeutists that intervals of from three to eight weeks should elapse between intensive applications of gamma rays, providing there is no evidence of injury to normal tissue. Fractional applications follow the same general rule as given in Chapter XIX.

Protection.—For complete protection all radium applicators when not in use, should be surrounded by lead of a thickness of several centimeters. It requires 30 cm. of lead to completely absorb the most penetrating gamma rays. When in use the radiating surface when possible, should be backed by a thick layer of lead. This, however, is not always practicable. In any event the operator or assistant should remain at a distance of several feet or preferably in another room, during the greater part of the exposure. It is not wise and very seldom necessary for the operator to hold the radium on the lesion. It can be held on by the patient, fixed in place by zinc plaster, dental compound, etc.

The radiologist should not handle the applicators with the fingers. Flat applicators can be removed from the case and applied to the patient by means of handles supplied for this purpose. Tubular applicators can be handled and manipulated with a pair of suitable forceps.

In instances where it is necessary for a technician to hold the applicator in place, the applicator should be backed with heavy lead and the radiating surface pointed away from the operator.

Care should be taken not to have photographic material, unless suitably protected, in the vicinity of radium applicators.

Equipment.—This will depend upon the magnitude of the work attempted. If radium is to be used solely and extensively it will be advisable to install an emanation outfit, a gram of radium, and obtain the services of a competent physicist and technician. If combined therapy is anticipated—roentgen therapy and radium therapy—but still on a large scale, one or two hundred milligrams of radium element divided into needles and tubular applicators with perhaps two or three flat applicators will suffice. In dermatological practice (combined therapy) one may begin very modestly with a flat applicator of full strength and gradually increase the number of applicators according to requirements and financial possibilities (Chapter XIX).

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CHAPTER XIII.

CHEMICAL, BIOCHEMICAL AND BIOLOGICAL EFFECT OF *X*-RAYS AND RADIUM.

CHEMICAL ACTION.

BOTH *x*-rays and radium rays are able to effect alterations in elementary substances and in simple and complex organic and inorganic compounds. The chemical change is one of oxidation but the actual physical process is atomic as well as molecular and is apparently brought about through the process of ionization. The chemical action of radium is greater than that of the *x*-rays because of the marked chemical activity of the alpha and beta rays. Silver bromide is reduced to metallic silver (photographic action); platinocyanide of barium is changed from the crystalline to the amorphous state with consequent change in color (dehydration); iodoform in chloroform undergoes a color change and free iodine is liberated. Alpha rays, particularly, are able to oxidize such metals as mercury, aluminium, lead and platinum. Radium dissolved in a weak solution of hydrochloric acid liberates free hydrogen and chlorine, also oxygen and hydrogen. Gaseous compounds are decomposed, ammonia yielding hydrogen and nitrogen; carbon monoxide, carbon and oxygen, etc. Not only are complex molecules broken down but also they are built up through the process of synthesis, nitrogen and hydrogen forming ammonia; carbon and oxygen combining to produce carbon monoxide, etc. Lubricants, paraffin, wax, paper and even the higher fatty acids are decomposed by prolonged exposure to alpha and beta rays. Both *x*-rays and radium rays will discolor glass and make it brittle.

BIOCHEMICAL ACTION.

Considerable experimental work has been done by biologists and physiological chemists in an attempt to determine the action of radium, particularly alpha and beta rays, on the higher fatty acids, organic colloids and enzymes. Schwarz observed a decomposition of lecithin upon which was based the so-called lecithin theory. His observations, however, have been corroborated by only two or three out of many experimenters. A number of investigators have shown that both radium and *x*-rays possess the property of modifying the production and the action of some enzymes and ferments. Inasmuch as cells contain a great many kinds of enzymes which are necessary to their growth, reproduction and function, it is obvious that a knowledge

relative to the effect of radiation on these important substances is of the utmost importance. Work has been done on many enzymes—pepsin, trypsin, ptyalin, amylopsin and substances such as fertilizin which probably contain enzymotic bodies. The findings of various workers are not in accord, but the opinion seems to prevail that small doses accelerate and large doses inhibit the production and action of these substances. Many believe, also, that autolytic or katabolic enzymes are more easily affected than those of opposite or synthesizing function.

Slight changes have been noted in globulin and nucleo-albumin, the alteration being apparently physical rather than chemical. Solutions of starch are changed to dextrin and soluble starch.

Microörganisms.—Considerable experimentation has been conducted to show the effect of radium and *x*-rays on animal organisms such as the protozoa, bacteria, etc., while the vegetable fungi have apparently been neglected. The protozoa and organisms of this type are resistant to irradiation, the lethal dose being a large one. Broadly speaking the most sensitive cells seem to be those containing a more fluid protoplasm and low chlorophyl content. In general the polynucleated forms are more readily affected than are the mononucleated. The activity of the sensitive types is stimulated by small doses, but with increased exposure they become lethargic, fail to reproduce and finally die.

Bacteria.—The literature contains very few recent references of carefully controlled experiments with *x*-rays or gamma rays. Most of the references found are old and with few exceptions they give negative results. (Rieder, Rudis-Jicinsky, Berton, Minck, Wittlin, Blaize and Sambuc, Bergonié and Mongour, Smith, Lyon, Delepine, Wolfenden and Ross, Zeit and others.) Considerable work has been done with the alpha and beta rays. These rays are able to interfere markedly with cultures even to the point of complete destruction. The effect is due entirely to the action of the rays on the organisms, not on the medium. Chambers and Russ sterilized cultures of the following bacteria by employing 0.5 millicurie per cubic centimeter. The suspension of the organisms in culture was approximately one million per cubic centimeter:

Bacillus coli communis	1 hour, 5 minutes
Staphylococcus aureus	2 hours
Bacillus pyocyaneus	3 hours, 10 minutes
Bacillus anthracis	3 hours, 20 minutes
Bacillus tuberculosis	4 hours

The lethal dose of beta rays will be, in all probability, worked out eventually for all the important bacteria in culture and experiments will undoubtedly be made to determine the effect of irradiation on bacteria inhabiting human tissues. At present about all that can be said is that large doses of beta rays will kill bacteria in culture to a depth of about 2 mm. of gelatine. In other words it is the "soft" beta rays that seem to be most effective. The fact that the result is

obtained by beta rays of very little penetrating power and that the lethal dose is a large one suggests that the effect of radiation on bacteria is of no value in the treatment of disease. But it must be remembered that beta rays are produced in the tissues during the passage of gamma and *x*-rays. It may be, therefore, that the direct bactericidal action of radiation is of therapeutic importance.

EMBRYOLOGY.

X-rays and radium exert a most profound influence on all developing forms of animal life. Extensive work has been done by a large number of scientists on the ova and larvæ of echinodermata, nematoda, mollusca, planorbis, fishes, amphibia, birds, insects and mammals. The result depends both upon the dose and the stage of development. Broadly, a cell undergoing division or about to do so is very easily modified. During the rest stage a comparatively large dose is required. A small dose accelerates the rate of subsequent division while large doses retard or inhibit. Microscopically a marked disturbance is found in the nucleus, especially in the chromatin. Not only can growth be accelerated or inhibited, but by modifying the ovum in a very early stage of development, subsequent cells inherit abnormal characteristics resulting in a faulty development of the animal as a whole. The result may be a monstrosity or the underdevelopment or overdevelopment may be confined to one small part.

It is possible to arrest development of any one part of an animal as, for instance, a limb, by confining the exposures to this part, administering large doses, and employing very young subjects. Long ago attention was called to the danger of applying long-continued treatment to the epiphysial regions in young children. While this possibility must be borne in mind it is exceedingly doubtful if an amount of radiation sufficient to retard development would ever be administered in the treatment of disease with the possible exception of tuberculosis. In twenty years of practical roentgenology no cases of arrested development have been recorded. In experimental work, if the development of some important organ is interrupted—as, for instance, the brain, the effect will be noted in other parts of the body. It has been suggested that the *x*-rays, as administered to the scalp in the modern treatment of tinea tonsurans, a disease occurring at any age under that of puberty, might produce immediate or remote injurious results. Such treatment has been administered to thousands and thousands of children over a course of fifteen years and no injurious results have been noted—the dose reaching the brain is entirely too small for anything more than a possible slight stimulation.

Intense irradiation of pregnant small animals (guinea-pigs and rabbits) results in retarded growth of the fetus and usually the birth of a dead fetus. The result will naturally depend largely upon the age of the fetus. If well developed it will respond in a manner similar to

an adult; if embryonic the change will be in relation to the dose and to the stage of development—retardation, irregularities, inhibition. The effect on the adult is largely confined to the lymphatic system. It is possible to kill mature small animals with large doses and it is not improbable that death is the result of this action on the hematopoietic system.

Edelberg administered 146 X in the course of three months (filtered) to the abdomen of a woman, by the cross-fire method, in the treatment of visceral cancer. Pregnancy occurred during the treatment, the last 35 X being given after conception occurred. A perfectly normal baby was born at term.

Plant Life.—It is interesting, though not surprising, to know that the effect of *x*-rays and radium in the vegetable kingdom is similar to that in the animal kingdom. Here, too, the result depends upon the dose and the stage of development. It is possible to stimulate growth, to retard growth, to prevent fertilization and to effect complete arrest of development, just as in animal life. The alpha and beta rays are most effective and seeds in the active stage are more susceptible than those in the resting stage. To add to the analogy Levin found that the development of crown gall, a growth in plants due to bacteria and composed of a rapid proliferation of young, undifferentiated cells and which is analogous, histologically and in other ways, to human cancer, could be prevented by suitable exposure to *x*-rays.

Schwarz found that $\frac{1}{12}$ X caused beans to grow rapidly. Double the dose retarded growth. The effect was the same whether the *x*-rays were applied before the beans were planted or after they began to sprout. The result was similar in the case of beans exposed four weeks after planting but those exposed eight weeks after planting did not show nearly the same degree of sensitiveness. Promsby and Dreyon, and Hussakof obtained similar results. Hussakof's article deals with both plants and animals and contains a good bibliography.

Biological Explanation of the Effect of X-rays and Radium.—Numerous attempts have been made to explain the phenomena subsequent to irradiation of normal and pathological tissue. The microscope shows many of the histogenetic phenomena but the morphological picture fails to explain the fundamental changes. The physiological chemist has demonstrated important biochemical alterations and the physicist has shown us that most of the changes produced by these agents are atomic—a process of ionization. What takes place in the cell, how and why? Three hypotheses have been advanced in answer to these questions:

1. *Lecithin Hypothesis.*—Schwarz found that egg yolk was decomposed after irradiation and he believed that the large lecithin content had been altered. As lecithin is an important constituent of the animal cell any alteration in amount or composition of this substance might well modify the ordinary course of development. He believed that the changes in the chromatin as revealed by the microscope were

secondary to a primary decomposition of the lecithin. Suffice it to say here that recent experiments have not only failed to corroborate the hypothesis but have forced it to the background.

2. *Chromatin Hypothesis.*—This theory was developed by the three Hertwigs and is based on very extensive and intensive laboratory work. They demonstrated that the only cell structures to be visibly damanged were the chromatin and the chromosomes. The spindles, asters, centrosomes, etc., were apparently unaltered. From this the Hertwigs deduced that the chromatin was directly injured by the radiation, that it was the primary injury and all subsequent developments were consequent to it. Later cytological investigation has demonstrated that cell organisms other than chromatin and chromosomes are altered, also that there are important biochemical changes occurring in the cell which apparently precede the morphological alterations.

3. *Enzymatic Hypothesis.*—Packard, who is responsible for this theory, bases the hypothesis partly on personal cytological research and on the known facts relative to the action of radium on certain enzymes which are present in all cells. He observed that, morphologically, several of the cell organs showed marked changes from the normal and in a manner that suggested indirect rather than direct action. He is of the opinion "that the radium radiations act indirectly on the chromatin and protoplasm by activating autolytic enzymes which bring about a degeneration of the complex proteids and probably by affecting other protoplasmic processes in the same manner."

There is evidence in support of the enzyme modifiability theory among which is Richard's work on enzymes and especially on fertilizin. This is about as far as we can go in biological theory. We know that young cells,[1] embryonic cells, cells that are undergoing rapid multiplication, undifferentiated cells, and actively secreting cells are more sensitive to radiation than are mature, differentiated and inactive cells. It is believed that all the phenomena subsequent to radiation are atomic. It may be that the final explanation will be based on physical or chemical knowledge; that it is the disintegration of the atom by ionization in the chemical constituents of the cell that produce the morphological changes. And that it is the stability of the atom and the time of its disintegration in relation to the cytological process that governs the subsequent observable alterations.

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uterine fibroid as originally conceived by Albers-Schönberg, Haenish, Bordier and the staff of the Freiburg Clinic. It is possible to effect an artificial menopause by the application of x-rays, radium or a combination of the two agents, without apparent injury to the skin or other abdominal tissues. The amount of irradiation necessary in the treatment of cutaneous affections is never sufficient to bring about sterility nor to endanger the ovaries. Female technicians, however, should be adequately protected.

BLOOD AND HEMATOPOIETIC SYSTEM.

It has long been known that the x-rays are capable of reducing the leukocytic count in leukemia. This fact was first noted by Senn in 1903. Very soon the disease was being more or less successfully treated by Pancoast, Pfahler, Goldhorn and others. It was soon observed that the enlarged leukemic spleen and glands were reduced and later, that the glandular hyperplasia of Hodgkin's disease could be controlled, also that the cutaneous lesions of mycosis fungoides and leukemia cutis would quickly disappear under the influence of roentgenization. In other words it was determined by clinicians that the x-rays were able to markedly influence pathological lymphoid tissue.

This information caused considerable perturbation among roentgenologists with the result that practically all x-ray workers had their blood examined. The result, fortunately, was of such nature as to negative the justifiable alarm. There were a few instances of lowered red cell and leukocytic counts but the variations in this respect among roentgenologists were no greater than among average individuals of various occupations. In this connection Schwarz avers that he found evidence of injury to the hematopoietic system in 10 roentgenologists who had been exposed to the x-rays over long periods of time. He also cites 2 fatal cases of leukemia in x-ray workers and 1 case in a chemist engaged in the production of radium. Mottram and Clarke found leukopenia in persons who handle radium.

Thanks to the careful experimental work of Helber and Linser, Benjamin, Reuss, Sluka and Schwarz, Tartarsky and others, it is now known that very large doses of x-rays administered to small animals will markedly decrease the number of leukocytes in the circulating blood. In fact, if the exposure is of sufficient strength, the blood may even become entirely free of white cells before death. The lymphocytes are the most susceptible, the polymorphonuclears are less sensitive and the erythrocytes least of all. Tartarsky conducted an experiment that seems to prove that the white cells may be destroyed by direct action. He made a prolonged exposure to a rabbit's ear and obtained an immediate although transient leukocytic reduction. When the irradiated area includes lymphoid tissue the numerical drop in white cells is more pronounced and of longer duration. When the spleen, glands and long bones are subjected to one intense dose of

x-rays there is an initial increase in all the cellular elements of the blood, particularly of the lymphocytes. This is followed in a few hours by a reduction of all the circulating cells but especially of the lymphocytes. The leukopenia reaches its maximum in from twenty-four to forty-eight hours after which there is a slow return to the normal, three or four weeks being required for complete recovery, assuming that the injury is not beyond repair. Small doses either have no effect on the normal blood picture or there will be a temporary leukocytosis, mainly a lymphocytosis. The result will depend naturally upon the dose, the intervals between exposures, and the parts irradiated.

All lymphoid tissue is very sensitive to irradiation being, in susceptibility, next to the testes and ovaries. After intensive irradiation hyperplastic changes have been observed in the bone marrow, while the spleen and lymphatic glands show atrophy and reduction in size.

Murphy, Morton, Ellis, Taylor, Hill and Nakahara, of the Rockefeller Institute, who had long been interested in the lymphocyte in relation to immunity, employed the x-rays for purposes of lymphocytic control. The x-rays were administered by Witherbee. Their early work was in connection with experimental tuberculosis. Ordinarily it requires from five to seven weeks to obtain a tuberculous growth in the peritoneal cavity of an inoculated guinea-pig. If the normal number of lymphocytes is reduced by about one-half and this low count is maintained for about ten days, the peritoneal inoculation, if positive, will show gross lesions within this time. One application of the x-rays is all that is required and there is no apparent modification of the general health of the animal. Thus there has been developed a rapid method of diagnosing tuberculosis. The inference is that the lymphocyte directly or indirectly is the natural defense of the organism against tuberculosis. By lowering or destroying this defense the host is at the mercy of the invader.

Of particular interest is the work of these investigators in the field of cancer research. Spontaneous cancer is common in white mice and such tissue will continue to grow when transplanted into another animal of the same species. By administering stimulating doses of x-rays to a healthy animal, obtaining thereby a numerical increase of the circulating lymphocytes, the cancerous tissue transplanted during the lymphocytosis fails to take. If it is returned to the original host it grows. If, on the other hand, the mouse in which the cancer is transplanted is subjected to a dose of x-rays sufficient to effect a marked lymphocytic reduction, before, during or shortly after the transplantation, the graft will take and grow rapidly.

In a recent article Prime states that he was unable to reduce immunity to experimental cancer in rats by lowering the lymphocytic count.

As a result of these experiments a number of practical roentgenologists have attempted the control of cancer by indirect x-ray treatment, that is, by exposing lymphoid tissue rather than the tumor itself.

Thus far the results have not been encouraging, but the author is not aware of any carefully conducted experimental work in this line in human cancer. The theory is interesting and has worked successfully in at least one type of cancer in a lower animal. In this connection it is significant that in the human skin there is always a lymphocytic infiltration at the very beginning of cancer evolution and the infiltration seems to be greatest in the slow growing and relatively benign types of epithelioma (basal-cell epithelioma).

Knudson and Erdos made a metabolism study of a case of leukemia during radium treatment. Their conclusions are as follows: "The excretion of total nitrogen, urea, ammonia and phosphates are enormously increased immediately after the action of radium.

"The uric acid output is only slightly increased compared to other nitrogenous constituents.

"Surface applications of radium over the spleen accelerates the disintegration of nuclein tissue, resulting in the above increases. The uric acid which would be expected to be formed by disintegration of nuclein is probably broken up further so that it is not increased.

"The phosphates show the most remarkable results, increasing as high as 400 per cent., at times, over the excretion at the beginning of treatment."

THYROID.

Irradiation of the thyroid gland results in inhibition of secretory function. Microscopically very little alteration has been noted. In practical work it is possible, as a rule, to overcome all the symptoms of hyperthyroidism, but the gland if enlarged, rarely undergoes reduction in size (Pfahler and Zulick, Dowd and others).

Practically nothing is known relative to the effect of irradiation on such ductless glands as the suprarenals and the pituitary body. The thymus gland, being a lymphoid structure, is easily influenced (Veau, Rudberg, Aubertin and Bordet, Lang, Friedländer, d'Oelsnitz and Paschetta and others). That the same is true of the tonsils is shown by recent work done in the Rockefeller Institute by Murphy, Craig, Witherbee, Hussey and Sturm.

EYE.

The mature eye is resistant to irradiation but large doses may effect blepharitis, conjunctivitis, keratitis and modifications in the aqueous humor. Repeated exposures over a long period of time may cause atrophic changes in various parts of the eye. Tribondeau and Belley found the immature eye very sensitive. Comparatively small doses produced cataract, delayed pigmentation of the iris, degenerative changes in the retina and vitreous humor and diminution in the size of the eyeball.

NERVOUS SYSTEM.

Irradiation will seriously interfere with the development of the brain and cord in embryonic life. The mature nervous system is very resistant. There is no record of injury to the brain, cord or peripheral nerves in practical work excepting in cases of radiodermatitis in which case the peripheral nerves are affected. Experimentally it is possible to cause convulsions, paralysis and other symptoms in small animals especially when young. Microscopically the nervous manifestations seem to be secondary to vascular changes.

DIGESTIVE SYSTEM.

With the exception of the spleen, the intestines appear to be more sensitive to irradiation than other abdominal organs. Experimentally, following intensive exposure, the intestinal wall is congested, degeneration of the epithelium and connective tissue occurs and there is an atrophy of the secreting glands, changes similar to those found in the irradiated skin. In practical work, even with the large doses employed in the treatment of uterine fibroma and malignant growth of the abdominal viscera, there is no evidence of serious injury to any part of the digestive system. In one or two days after cross-fire treatments there may be nausea, vomiting and diarrhea but these symptoms also occur when the treatment is applied to some other part of the body. However, as pointed out by Knox, it may be well to reserve opinion for a long time before agreeing that enormous and repeated doses of penetrating rays do not injure the deep tissues, as such evidence of injury may be manifested only through the development of sequelæ many years after the treatment. Stein, in 1916, reviewed the literature and found a few reports of complications and sequelæ following deep therapy. He mentions intestinal atrophy, sclerosis of the pelvic connective tissue, adhesions, arteriosclerosis and other changes. It must be admitted, however, that the Freiburg technic and deep therapy in general has been employed very extensively over the civilized world for ten or twelve years with very little evidence of serious injury to the tissues.

The pancreas, liver and salivary glands seem to be quite resistant to irradiation. They do not appear to be injured in practical work. Experimentally it is possible to alter both the structure and function of these parts. The same statements may be made relative to the kidneys.

Warthin found degenerative changes in the kidneys of a patient who had received considerable *x*-ray treatment for leukemia, alterations which he thought might have been caused by the radiation.

Long-continued irradiation of the mammary glands is likely to reduce the activity of the secreting epithelium (Cluzet and Bassal).

Alterations produced by irradiation in muscles, connective tissue,

bloodvessels, secreting glands, etc., will be found in the discussion of the effects of radium and *x*-rays on the skin.

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CHAPTER XV.

CLINICAL EFFECT OF ROENTGEN RAYS AND RADIUM RAYS ON THE SKIN.

RADIODERMATITIS.

When the skin has been irradiated beyond the toleration point an inflammatory reaction results. When provoked by radium the reaction is termed radium dermatitis. If effected by the *x*-rays it is called radiodermatitis, *x*-ray dermatitis, roentgen dermatitis, *x*-ray reaction, *x*-ray "burn," etc. A reaction may result from a single intensive dose or it may be the cumulative result of several or many fractional applications. The term radiodermatitis may well include the reactions both of radium and the *x*-rays.

Latent Period.—After an erythema dose of *x*-rays or radium the first clinical manifestation of a reaction is seen usually about the end of the first week. Thus there is an interval of several days of clinical inactivity. This period of latency is variable in regard to duration as will be shown later in this chapter. Also, it is a period of considerable histological activity (see Chapter XVI). Heineke believes that the period of clinical latency is explained by the lapse of time between the destruction of the cell's capacity to reproduce and the subsequent natural death of the irradiated cell.

"ELECTRIC" ERYTHEMA.

Occasionally one encounters an erythematous reaction an hour or two after intensive roentgenization, especially when the irradiated area is surrounded by lead foil. The hyperemia endures a day or two and disappears without leaving pigmentation or other *x*-ray sequelæ. It may be accompanied by such subjective symptoms as burning, stinging and itching. Also, there may be an associated edema and, if the treatment happens to include the parotid glands, there may be a marked swelling of these glands. These early, temporary, and harmless reactions not infrequently occasion considerable alarm, not on account of the symptoms but because of the knowledge that true *x*-ray reactions of the third degree begin very soon after irradiation. Pfahler believes that they are caused by an electrostatic discharge and that they can be prevented by grounding the lead foil that is placed around the irradiated area for the purpose of protection. The phenomenon was noted by Schultz, Béclére and others years ago.

X-RAY AND RADIUM REACTIONS.

X-ray and radium reactions may be divided into two types—acute and chronic. The acute type is subdivided into three degrees, namely, first, second and third degrees.

First Degree.—The first degree reaction consists of a simple cutaneous erythema or hyperemia. This may vary from a hardly perceptible flush to one that is intensely red and associated with slight edematous swelling. The subjective symptom is burning or tingling; there may be itching. The reaction becomes manifest, as a rule, in from five to seven days and reaches a maximum of development in from ten to fourteen days, after which the bright red color changes gradually to a dull red, then to a brownish-red and disappears usually in the third or the fourth week. Pigmentation may remain for several weeks and there is likely to be some desquamation during the stage of involution. If the affected area involves a hairy part depilation is apt to occur during the third week. The alopecia may be temporary or permanent. Kaestle, and Janus, call attention to the fact that a hot bath or hot applications will provoke an erythema after intensive treatment.

Fig. 67.—First degree radiodermatitis. Area on arm shows a slight reaction while the area on the forearm shows a more intense reaction.

Second Degree.—There is no sharp line of demarcation between reactions of the first and second degrees. It is generally understood that if a reaction progresses beyond hyperemia and slight edema it is of the second degree. A second degree reaction is recognized by marked edema, vesiculation, erosion or superficial ulceration. The erythema of second degree reactions is likely to develop two or three days earlier than that of the first degree. In a few days the color is scarlet; it then becomes purplish-red or bluish-red—livid. In ten

days or two weeks the intense cutaneous edema destroys all or part of the epidermis with a consequent moist or exudative, eroded surface. This development may or may not be preceded by vesicle formation. The exudate drys into a crust which is likely to be impetiginous but which may be firm and dry. The subjective sensation is first tingling and burning and then a burning pain which may be very distressing. Second degree reactions will heal spontaneously in from six weeks to three months depending upon the intensity of injury and the extent of surface involved. Hair in the irradiated area will fall out in three weeks and the resulting alopecia will be permanent. The regeneration of epidermis is complete and if the connective tissue has not been badly

FIG. 68.—Second degree reaction of mild type. Here there is edema with some vesiculation and exudation.

FIG. 69.—Second degree radiodermatitis of severe type. There is destruction of the epidermis with exudation and crusting and severe pain. Reaction required about two months to disappear.

damaged and sequelæ do not develop the final result is clinically normal skin.

Third Degree.—There is no line of demarcation between reactions of the second and third degrees. It may be said that if the ulceration or necrosis involves the true skin the reaction is one of the third degree. The first evidence of reaction (erythema) is likely to be seen within twenty-four or forty-eight hours and in a few days it becomes of the livid or bluish-red type. In two or three weeks the congestion and edema of the deep tissues become intense even to the extent of board-like hardness on palpation; the epidermis exfoliates, leaving a denuded derma. One of two things may now happen. The injured cutis and subcutaneous tissue may undergo rapid ulceration or the affected parts may form a dry, hard, necrosed mass with a crusted surface—dry gangrene. In the latter instance the necrosed mass, surrounded by intense inflammation, will remain apparently stationary for weeks or months; eventually it is converted into a slough which is finally thrown off, the result being a deep ulcer. In either instance, after a period of considerable ulcerative activity, assuming that the injury is beyond immediate repair, the ulcer develops distinctive characteristics. The abrupt margins and the deep-seated floor produce a punched-out appearance. The absence of granulation tissue and the subsidence of reactive inflammation creates a dry, glistening floor. In

FIG. 70.—A typical third degree, indolent, *x*-ray ulcer. Note the abrupt margin, the shiny dry base and the absence of granulation tissue. This ulcer required nearly two years to heal and the patient suffered excruciating pain for the first eight months.

other words there is an exceedingly indolent ulcer. This is the usual clinical picture. There may be unhealthy granulations associated with a heavy mucopurulent discharge. The detailed clinical picture will naturally vary with the degree of injury and the successful or abortive attempts at repair, together with the action of bacteria. The ulcer

FIG. 71.—Third degree radiodermatitis of the finger tips.

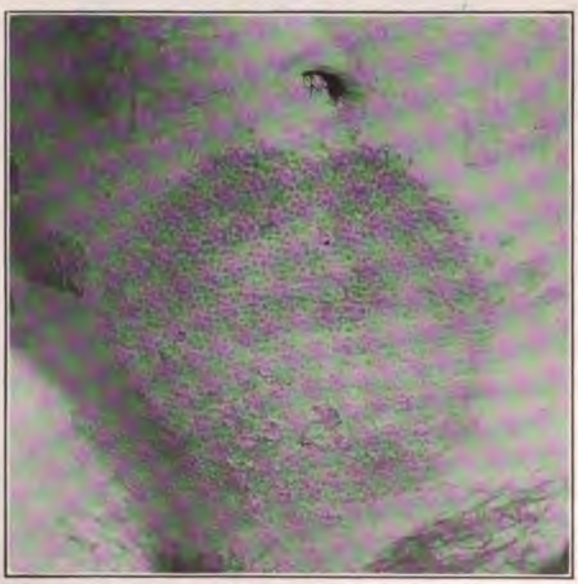

FIG. 72.—Follicular radiodermatitis of a mild second degree.

may involve part or all of the true skin, the subcutaneous tissue and even the muscles. Small, comparatively superficial ulcers may begin to granulate in a month or two, healing being complete in a few months. The larger and deeper ulcers usually remain indolent for many months, even years. There may be, on the other hand, slow but steady healing and occasionally an ulcer of long standing will suddenly begin to granulate and heal rather promptly. As a rule, however, if an ulcer has not undergone spontaneous repair within a year or eighteen months it will persist indefinitely.

The cicatrix following a third degree ulcer may be healthy, pliable and possess the color and palpable consistence of normal skin—in other words, of exceedingly good cosmetic quality. The end-results, unfortunately, are likely to be marred by undesirable, disfiguring and even dangerous sequelæ. These possible sequelæ do not, however, include cicatricial contractions and ectropion and it is very uncommon to see hypertrophic scars, keloids or keloidal bands.

The chief subjective symptom of a third degree reaction is excruciating pain of a burning character. The pain usually subsides just before healing begins. Indolent ulcers remaining exceedingly sensitive indefinitely but the individual does not actually suffer after six, eight or twelve months.

Unusual Features.—The author has encountered two instances of what might be termed follicular radiodermatitis (radiodermatitis folliculata). In both instances there was a moderate, diffuse erythema with slight desquamation, over a circular area six inches in diameter. The follicular orifices and the perifollicular regions were slightly elevated and of a much more intense red color than that of the interfollicular portions of the affected area. In one of the patients there was a follicular atrophy following the disappearance of the eruption. The appearance was not unlike that seen on the extensor surface of arms in adults who have the atrophic remains of a former keratosis pilaris.

Occasionally, in reactions of second and third degrees and even those of the first degree, there is considerable deep-seated edema of the unexposed adjacent tissue. This is especially likely to occur if the radiodermatitis is in the vicinity of the eyelids.

Variations in the period of clinical latency are not uncommon. The author has seen erythema develop within two or three hours after a radium application and persist for two or three weeks. In one such instance the involved areas showed telangiectasia after the lapse of over a year. In another instance the erythema was followed by persistent pigmentation. First degree x-ray reactions are manifested, at times, within twenty-four or forty-eight hours. Conversely, the appearance of both mild and severe reactions may be delayed several days, weeks or even months. The author has encountered a number of such instances, following single intensive applications. Pfoerringer relates an interesting example of delayed reaction. The great toe of the right foot of a patient was given a total dose of filtered x-rays

amounting to 154 X (H77) through three ports of entry (cross-fire), during a period of six months. Three months after the last exposure the irradiated skin became livid red, scaly and painful but did not ulcerate. No other cause could be determined. Before accepting this as evidence of a delayed reaction it would be necessary to exclude positively the application of irritating local remedies, such as liniments, subsequent to the treatment.

Complications.—Probably the most common and most annoying complication of exudative or ulcerative radiodermatitis is eczema or dermatitis of the infectious eczematoid dermatitis type. This affection, originally described by Engman and later by Fordyce, appears to be a sensitization on the part of the skin to discharges from wounds, ulcers, sinuses, etc. Whether the sensitization is in relation to bacterial products or to other chemical ingredients in the discharge is unknown. The dermatosis is not communicable but it is auto-inoculable. When complicating radiodermatitis the first objective indications of its presence are a redness and swelling with itching and burning or stinging, beyond the confines of the previous inflammation. The new dermatitis, unless checked, soon becomes exudative and spreads by peripheral extension and by auto-inoculation until one or several parts of the body are involved. The author has seen universal exudative dermatitis follow a third degree ulcer no larger than a quarter of a dollar.

A number of instances of vegetations occurring in the course of acute radiodermatitis of the second degree have been observed. The lesions developed just previous to the first signs of repair. They ranged in size from a lentil to a bean, were firm but not hard in consistence, yellowish-red in color, and presented a moist surface. They resembled the flat condyloma of syphilis. It is possible that the lesions consisted of an overgrowth of unhealthy granulations and this hypothesis is probable because of their spontaneous disappearance in two or three weeks. They possessed the clinical appearance of proliferated epidermis (acanthosis) which if true, would assume a proliferative type of acute radiodermatitis.

Sequelæ.—The sequelæ of radiodermatitis and radium dermatitis are, unfortunately rather common. Some of them are disfiguring while others are dangerous. The sequelæ are commonly spoken of as chronic radiodermatitis.

TELANGIECTASIA.

Telangiectasia (dilated cutaneous vessels) is more common after second and third degree reactions than after that of the first degree. But it should be particularly and forcibly emphasized that a very pronounced telangiectasia may follow a mild erythema provoked by either *x*-rays or radium. The dilated capillaries are seen as red puncta and delicate to coarse, straight to serpentine, more or less parallel vessels, which produce a brilliantly red network, which, at a distance, may appear as a diffused erythema. The color disappears

under diascopic pressure. At times the telangiectasia, at a distance, presents a macular or mottled appearance. On close inspection the macules are seen to be composed of an exceedingly delicate capillary plexus.

Years ago it was common to see a very large area of telangiectasia, the entire abdomen for instance, with widespread atrophy and a central indolent ulcer or cicatrix, with multiple keratoses scattered over the affected area. In these instances the telangiectasia seemed to radiate peripherally from the center and produced a most striking picture. Telangiectasia following second and third-degree reactions is usually of the radiating type.

FIG. 73.—Xeroderma pigmentosum, showing telangiectasia, pigmentation, keratoses and epitheliomata. Note the similarity to the so-called x-ray skin.

Telangiectasia may develop within a few weeks or a few months subsequent to the advent of the reaction, but as a rule it makes its appearance in about a year. If telangiectasia has not evolved in eighteen months it is safe to assume that it will never develop. While it is not certain yet there is reason for believing that telangiectasia

never occurs without at least one previous mild reaction. Certainly such a phenomenon is uncommon. The dilated vessels rarely if ever disappear spontaneously.

FIG. 74.—Telangiectasia, atrophy, pigmentation, keratoses and at the lower part a beginning epithelioma—all subsequent to severe radiodermatitis.

ATROPHY.

Cutaneous atrophy is an exceedingly frequent sequel. It practically always follows second and third-degree reactions and may occur as a result of even mild reactions of the first degree. The atrophy may be of several different clinical types. After mild and moderately severe reactions the irradiated area may have a slightly lower level than that of the normal skin. The most common manifestation of atrophy is wrinkling. This may be so slight as to be imperceptible excepting when involving the face, particularly near the mouth, and even here it may be noticed only when the muscles are used in such acts as smiling, laughing, weeping, mastication, etc. If of a more marked degree the wrinkling may be noticeable even when the part is in repose. The extreme grade of this type of atrophy is seen in the skin of the extensor surfaces of the articulations where it may constitute an anetodermia,

After severe reactions the skin may be thin, shiny, dry, scaly, semi-translucent and wrinkled—resembling parchment. In such instances it eczematizes and fissures readily and may reveal a lessened resistance to various kinds of traumatism. Still another type of atrophy is the hidebound skin, where the skin is attached to dense underlying tissues. This type somewhat resembles scleroderma and is common after third-degree reactions. It may also occur after repeated first-degree reactions.

Like telangiectasia, atrophy can develop in a few weeks but it is most likely to appear in about a year. If it has not developed in a year or eighteen months it is not likely to appear. Unfortunately the defect is permanent. Atrophy may result without an antecedent visible reaction, the result of long-continued fractional treatment.

Fig. 75.—Depigmentation following radium dermatitis. Also permanent alopecia above the ear. The depigmentation can be successfully camouflaged by means of the stain mentioned in this chapter.

PIGMENTATION.

Tanning or pigmentation is common after reactions of all degrees. As a rule it will disappear in a few weeks but it may persist for several months and even for a year or two. After very severe reactions the pigmentation may be permanent. After severe reactions there may be depigmentation instead of hyperpigmentation. This is seen most often in very dark skins.

Lentigo and diffuse pigmentation may occur to a troublesome degree in certain individuals, particularly brunettes, as a result of a few mild

exposures—a dose well within that required to produce a reaction. In such instances, if the treatment is discontinued, the freckles and diffuse tanning will disappear in a few weeks.

HAIR FOLLICLES.

When hairy parts are irradiated with sufficient intensity to effect a first degree reaction, defluvium will occur anywhere in from one to four weeks.

Usually the hair begins to fall out about the third week and ceases to fall by the end of the fourth week. Complete and permanent alopecia, with the exception of a few scattered coarse hairs and more or less fine lanugo hair, follows reactions of the second and third degree and well-marked reactions of the first degree. A fairly complete defluvium will practically always follow even a mild and transient erythema. The hair will usually regrow after a mild reaction but it may not do so. The follicles have been known to regenerate even after a well-marked erythema that endured for two weeks. It is well to bear in mind, however, that follicular regeneration is never certain after even a very mild reaction. It is possible, by the repeated application of suberythema or smaller doses, to effect permanent alopecia without the advent of erythema. If regeneration occurs the hair will begin to grow again in from one to six months, depending upon the dose administered. If alopecia is present at the end of six months it will be permanent. The mature type of hair depilates more readily than does lanugo or downy hair.

SWEAT-GLANDS.

The coil glands may regenerate completely after a first-degree reaction, but there is likely to be a noticeable diminution in the secretory function. A second-degree reaction will markedly reduce the activity of the glands and they are totally destroyed by third degree reactions. The sudoriferous function may be lessened and even permanently arrested by repeated exposures without an accompanying reaction.

SEBACEOUS GLANDS.

A single first-degree reaction may permanently impair the function of the sebaceous glands although this is not the rule. Repeated erythematous reactions or a single reaction of the second degree will markedly reduce sebaceous activity as evidenced by a dry skin. Third-degree reactions completely destroy the sebaceous glands. As with the hair follicles and coil glands the sebaceous glands can be reduced or even destroyed by repeated mild irradiation without a visible reaction.

MUCOUS MEMBRANES.

While the author has no experimental data with which to prove the assertion, it is his distinct impression that the orificial mucous mem-

branes are more sensitive to *x*-rays and radium than is the skin. This is undoubtedly true of the buccal mucosa. It has been claimed that the vaginal mucosa is more resistant to irradiation than the skin and that this resistance is caused by the acidity of the vaginal secretion. The author cannot confirm these observations.

Radiodermatitis of the mucous membranes does not differ from that of the skin excepting for slight differences in the clinical picture. The erythema may be overlooked so that the reaction is apparently inaugurated with edema and erosion.

NAILS.

Radiodermatitis of the distal end of a finger, if severe, may result in a defluvium of the nail. As a rule the nail will regrow. Much more common phenomena are transverse or longitudinal ridging, slow growth and brittleness of the nail following severe reactions, repeated mild reactions, or long continued fractional exposures without reaction.

KERATOSES. LATE ULCERATION. CANCER.

Keratoses are prone to develop eventually in so-called *x*-ray skin. They are fairly common after third-degree reactions, infrequent subsequent to reactions of the second degree unless the reaction was severe and rarely occur as a result of a single first degree reaction. They may occur after repeated erythematous reactions and after frequent irradiation over a number of years without reaction. The lesions usually occur on skin that is atrophic and perhaps telangiectatic.

Keratoses are of several clinical varieties. The usual type is a slight elevation consisting of a thickened but firmly adherent horny layer. The lesions range in size from a pinhead, a lentil, a split pea to a dime. Another type consists of a perceptible thickening of the entire epidermis in addition to the adherent scale—acanthotic keratosis. Still another form is where, in addition to hyperplasia of the rete under the keratosis, there is an associated edema and vesicle formation. The vesicles are never well-developed; they occur under the thickened horny layer which becomes elevated; pressure will cause a drop of serum to exude. The condition is caused by a peculiar degeneration of the rete—dyskeratosis, and a degeneration of the upper part of the derma. *X*-ray keratoses, or *x*-ray warts as they are often designated, are likely to be exceedingly tender.

The warty excrescences may develop a few months after the healing of a severe reaction but, as a rule, it is several years before they make their appearance. These keratoses are not epitheliomata but inasmuch as some of them eventually develop into cancer they must be regarded as potentially dangerous—preëpitheliomatous degenerations.

Ulcers may develop months, usually years, after the healing of a severe reaction or in skin that has been subjected to repeated mild

FIG. 76.—Atrophy, excessive dryness, pigmentation, telangiectasia and marked keratos several years after a severe radiodermatitis.

Fi[illegible]—Prickle-cell epithelioma, numerous keratoses, atrophy, pigmentation an tela[illegible]. This photograph could well represent the so-called *x*-ray skin, sailor' ski[illegible]in or xeroderma pigmentosum. The patient is an *x*-ray technician.

reactions. Schmidt has noted ulcers occurring in from three months to a year subsequent to filtered treatments, without antecedent reaction. Many such ulcers are caused by traumatism acting on devitalized tissue. Such ulcers may heal spontaneously or they may persist, prove recalcitrant to treatment and eventually show malignant tendencies.

There is likely to be a somewhat constant exfoliation after the healing of severe reactions. The scales usually cease to form in a few months but may continue for a year or two.

Cancer, practically always of the metastatic epithelioma type, develops secondary to keratoses or to spontaneous ulceration. Epithelioma has been known to occur within a year after the healing of a third-degree reaction but, as a rule, this very unfortunate development does not take place for several or many years.

CHRONIC RADIODERMATITIS.

This term, by some clinicians, signifies an indolent ulcer resulting from an acute third-degree reaction. Others employ it to indicate the so-called *x*-ray skin, a skin that shows one or all of the sequelæ already enumerated and which may be the result of a previous acute reaction or which may develop insidiously as a result of repeated, strong irradiation over a long period of time. It is obvious that a chronic radiodermatitis may be atrophic, hypertrophic or ulcerative. *X*-ray skin bears a striking resemblance to xeroderma pigmentosum and sailors' or farmers' skin, in which there is an idiosyncracy to sunlight or certain wave lengths thereof, and in which develop lentigo, cutaneous atrophy, ulcerations, keratoses and cancer.

"HARD," "SOFT" AND FILTERED RAYS.

There have been many misleading statements relative to the difference in effect on normal skin of "hard," "soft" and filtered roentgen rays. The biological action of radiation is due to that part of the radiation that is absorbed. Fewer short waves will be absorbed by a given thickness of tissue than long waves. But no matter how "hard" the radiation may be some of the short waves are absorbed by the skin. It should be obvious, therefore, that if "hard" rays are administered in sufficient amount the effect on the skin will be the same as with "soft" rays as there is no fundamental difference in the biological action of short and long *x*-rays. Naturally very "soft" rays will effect mostly the superficial tissue while very "hard" (filtered) rays scatter the effect more equally throughout a greater depth. Therefore a radiodermatitis produced by "soft" radiation will be more superficial in character than will that produced by "hard" radiation. This question was touched upon in the chapter on general physics and it will be discussed at some length in subsequent chapters. Let it suffice to say here that a first, second and third-degree radiodermatitis can

[illegible]

[illegible]

[illegible]

In the past, when using gamma rays, it was the custom to use lead as the filter and to place the lead-covered applicator in direct contact with the skin. A long exposure with such an applicator gave rise to severe, but superficial ulcerations—reactions that healed spontaneously in a few weeks. These reactions were supposed to be due to the gamma rays and they seemed to support the contention of F. E. Simpson and others who persistently insisted that *x*-ray reactions and radium reactions had little in common. We now know that such reactions are due to the very "soft" radiations from lead and that they can be prevented by placing suitable absorbing material (glass, leather, paper, chamois) between the lead and the skin.

TREATMENT.

First Degree.—There is no known way of preventing the onset of a reaction after an erythema dose has been administered. Various prophylactic measures have been suggested for use during the latent period. These consist of soothing agents, dilute solutions of acids, alkaline solutions, etc., but they are of questionable value. It is of the greatest importance to avoid stimulating or irritating applications previous to, during and subsequent to irradiation. For the erythema the following ointment and solution will suffice:

℞—Zinci stearatis		ʒj
Adipis lanæ		℥ss
Petrolati albi	q.s. ad.	℥j

Misce.
Sig.—Apply to affected parts at bedtime.

℞—Zinci oxidi,		
Magnesii carbonatis	āā	ʒj
Calaminæ præparatæ		ʒss
Aquæ hamamelidis		℥j
Liquoris calcis	q.s. ad.	℥iv

Misce.
Sig.—Shake well and sop on affected parts several times daily.

If itching is present 1 or 2 grains of menthol or 3 to 5 grains of phenol may be incorporated in the ointment. To the solution may be added from 1 to 10 grains of menthol and from 15 to 30 drops of carbolic acid.

During the acute stage soap and water should be avoided, cleansing being accomplished with one of the following mixtures:

℞—Phenolis liquefacti		gtt xv
Olei olivæ		℥iij
Petrolati liquidi	q.s. ad.	℥vj

Misce.

℞—Magma magnesiæ		℥iv
Petrolati liquidi		℥ij
Sodii boratis		ʒj
Aquæ rosæ	q.s. ad.	℥viij

Misce.

he produ[illegible] radiati[illegible] [illegible] effec[illegible]

T[illegible]

[illegible] dressing [illegible] extract [illegible] and

[illegible] with a [illegible] and [illegible] exuda[illegible] should [illegible] damage [illegible] the [illegible] from contact [illegible] affected [illegible] comes [illegible] with the [illegible] rise to [illegible] complica-

[illegible] possible to [illegible] as the [illegible] lotion and [illegible]

[illegible] 5[illegible]
[illegible] 5[illegible]

[illegible] and removed in the morning [illegible] solution. The calamine lotion [illegible] there is considerable discharge it [illegible] saturated wet dressings day and [illegible] In severe reactions the [illegible] pain and almost every [illegible] when first applied. [illegible]

To quote from Pusey, the emulsion or liniment is made in the following manner: "A wide-mouth bottle should be used, one large enough to allow a free shaking of the quantity of emulsion to be made—for example, a quart bottle for a pint of emulsion. The bottle should be clean and dry. The phenol, glycerine and oil of bergamot are first added to the oliver oil. The entire quantity of oil is then placed in the bottle, the bottle corked, and the oil shaken up in the bottle in order to be sure that the entire inner surface of the bottle and cork becomes covered with a film of oil. The tragacanth (finely powdered) is then added little by little to the oil and the mixture is thoroughly shaken until a yellowish, opaque mixture is formed. If this is properly done the tragacanth becomes evenly mixed through the oil. This is essential in order to get a good emulsion. Then about 4 ounces of water are added and the mixture vigorously shaken. This will produce a yellowish, creamy emulsion. The calamine and zinc oxide are mixed dry and then stirred up with the remaining 8 ounces of water in a separate container. The easiest way to do this is to take a wide-mouthed bottle, put in the zinc oxide, calamine and water and shake it. This mixture of powder and water is then added, an ounce or two at a time, until the quantity is brought up to a pint. After each addition of the suspension the emulsion is vigorously shaken." If properly made this forms a smooth, creamy, pink emulsion which keeps indefinitely, which does not separate on standing and which does not break into droplets when applied to the skin.

In the non-exudative stage a cream may be more cooling than an unguent. Unguentum aquæ rosæ (U. S. P.) may be employed for the purpose or one of the following creams in which may be incorporated such chemicals as zinc oxide, zinc stearate, calamine, etc., according to indications. From ½ to 2 grains of menthol may be added for the cooling effect.

COCOA-BUTTER CREAM.

	Per cent.
℞—Olei theobromatis	18
Ceræ albæ	10
Adipis lanæ	6
Olei amygdalæ expressi	50
Aquæ	16
℞—Adipis anserini	65
Olei theobromatis	12
Adipis lanæ	15
Aquæ	8
℞—Olei olivæ	65
Olei theobromatis	5
Adipis lanæ	5
Ceræ albæ	5
Aquæ	20

The various almond and quince-seed emulsions, and witch hazel creams alone, or combined with other chemicals, can be used to advantage at times.

If none of the suggestions already given affords relief from the pain,

from 5 to 10 per cent. of anesthesin may be added to the ointment, paste, solution or emulsion. This drug at times seems to act exceedingly well. Beta-eucaine-lactate, in the same proportion, will afford relief in some instances. Occasionally a grain or two of menthol, phenol, eucalyptus or camphor, when added to the prescription seems to lessen the pain. Local remedies placed on a thick crust will be of little benefit. If not adherent it is preferable to remove the crust if there is much pain. If not, and there is no exudation, it is better to leave the crust alone.

Very weak ichthyol applications may prove beneficial at times. Ichthyol in the strength of from 1 to 3 per cent. may be added to the ointments, pastes and creams or the following lotion may be tried:

℞—Ichthyol		ʒss
Oleatum zinci,		
Magnesi carbonatis	āā	ʒij
Liquoris calcis	q.s. ad.	℥viij
Misce.		

In an editorial article Case suggests the use in radiodermatitis of Hull's treatment for ordinary burns. The formula for the application follows:

	Per cent.
Resorcin	1
Olei eucalypti	2
Olei olivæ	5
Petrolati	25
Paraffini	67

The hard paraffin is first melted and the soft paraffin and olive oil stirred in. The resorcin is next added, dissolved in half its weight of absolute alcohol and finally the oil of eucalyptus, when the wax has cooled to about 55° C.

Third Degree.—The most difficult problem in the treatment of reactions of the third degree is to obtain relief from the severe pain. Patients will welcome any new local application only to throw it aside in an hour or two. One remedy after another will be tried until the resources of the pharmacopœia and of the physician are exhausted. Fortunately, by that time the pain will begin to lessen and the remedy that is being used at the time, or the physician who prescribes it, will receive the credit. Psychological influence can be used to advantage; tact, patience and constant encouragement are essential. In addition to the remedies already enumerated an ice-bag placed on a wet dressing may effect temporary relief. During the stage of gangrene or sloughing, local remedies are of little use. The injection of local anesthetics in and around the affected area seems to afford very little comfort and is not a good practice. The weight of bed clothes, thick pads and bandages are not well borne and should be avoided.

It is almost always necessary to resort to the internal administration of sedatives for the first few weeks or months. Bromides and the coal-tar preparations are practically useless excepting in mild cases. Codeine and morphine will give relief but they must be used very

cautiously and intelligently in order to avoid the acquisition of a drug habit.

After separation of the slough the pain can usually be controlled by local applications. Slight stimulation is now indicated. For this purpose the ichthyol lotion or a zinc ointment or paste containing from 1 to 3 per cent. of ichthyol may be employed. Care must be taken not to injure or overstimulate the delicate granulations. If exuberant, they may be destroyed with the curette and a 10 per cent. solution of silver nitrate. It is permissible to stimulate sluggish granulation tissue by applications of silver nitrate, beginning with a 1 per cent. solution.

Indolent ulcers can often be made to granulate and heal by exposure to the sun or better still to the ultraviolet rays from the Kromayer or Alpine lamp. The exposures at first should be very mild but later the strength should be sufficient to effect a mild erythema of the adjacent normal skin. Two treatments a week will suffice. Scarlet-red ointment, ½ to 5 per cent. may be of benefit in some instances.

Probably the best treatment for a third degree radiodermatitis, if not too extensive and unsuitably located, is surgical excision. If the entire affected area is removed the pain ceases at once and healing is rapid. This saves months of agony, additional months of inconvenience and, most important of all, it precludes the subsequent development of sequelæ. During the acute stages it is difficult for the surgeon to ascertain the extent, especially the depth, of the injury so that surgical intervention may be a complicated matter. Furthermore, surgeons do not like to operate in such cases because the reparative powers of the tissues are so poor. In some instances ablation can be accomplished. In others a thorough curettage with subsequent skin grafting can be successfully carried out. In still others it is better to avoid surgical interference at least until the extent and degree of injury together with the ability to repair, has been determined. If an ulcer has not healed in a year it should either be excised or thoroughly curetted and grafted. Very successful work of this kind has been done by Porter and McArthur.

Gottheil reported an instance where a chronic x-ray ulcer healed rapidly after several autoserum injections. The lesion was improving at the time that the injections were instituted and it is probable that healing was spontaneous.

Treatment Advocated by Various Authors.—Dodd believes that baths containing sodium bicarbonate at the beginning of a reaction tend to reduce its severity. He has found the following prescription useful:

℞—Phenolis		ʒss
Glycerini		ʒj
Zinci oxidi		℥ss
Liquoris calcis	q s. ad.	℥viij

Misce.

Savil employs Hilton's method in the treatment of indolent, painful x-ray ulcers. This consists in making two semicircular incisions one

[illegible] These are allowed to heal by granula-

[illegible] advocated by Bogrow. This consists of [illegible] iodide internally and the application of an [illegible] acidified dioxide of hydrogen. The combi-[illegible] nascent iodine locally.

[illegible] chronic radiodermatitis Doumer employs gentle [illegible] applications of 20 per cent. lipoic acid in vaseline and the [illegible] for ten minutes daily. Dakin's solution has [illegible] in the treatment of chronic *x*-ray ulcers.

[illegible] of Sequelæ. *Pigmentation.*—The disappearance of freckles [illegible] pigmentation may be hastened at times by a liquid or [illegible] containing 2 grains of corrosive mercuric chloride to the [illegible]

℞	Hydrargyri chloridi corrosivi		gr. vj
	Glycerini		ʒj
	Tincturæ benzoini		℥ss
	Emulsionis amygdalæ	q.s. ad.	℥iij

Misce.

The emulsion may be applied to the affected parts two or three times daily. At times an ointment or cream is more efficacious. It may be applied at bed-time:

℞	Bismuthi suboxidum,		
	Hydrargyri ammoniati	āā	ʒj
	Olei lavandulæ		♏x
	Adipis lanæ		℥ss
	Petrolati albi	q.s. ad.	℥j

Misce.

These stimulating remedies should not be employed during or shortly after irradiation. During irradiation the following prescription may prove useful:

℞	Liquoris hydrogenii dioxidi		℥iss
	Glycerini		ʒij
	Aquæ rosæ	q.s. ad.	℥iij

Misce.

The solution may be applied to and rubbed into the skin several times daily. It should not be allowed to come in contact with the scalp, hair, eyebrows, eyelashes and mustache.

[illegible] may be temporary but it is likely to be permanent. It is always disfiguring. It usually occurs only after very severe [illegible]. There is no remedy known to the author that will develop pigment in the depigmented areas. The following formula is for a stain that is not soluble in water and if properly made it will remain on the skin in spite of washing. It can be removed at once with alcohol. It may be necessary to apply several coats before the light area matches the normal skin.

Fluidextract of walnut (juglans)	1 part
[illegible] per cent. solution of carmine in aromatic spirits of ammonia	2 parts
Alcohol	[illegible] parts

Telangiectasia.—A few large vessels may be successfully destroyed y means of electrolysis. In any case it is advantageous to destroy he larger vessels by this means. But it is quite hopeless to attempt he removal in this manner of extensive areas of telangiectasia, or ven of small areas where the dilated vessels are small and numerous. The technic consists of inserting a hypertrichosis needle into the umen of a vessel. The needle-holder is connected with the negative pole of a galvanic or direct, continuous current. The positive pole is connected to a wet sponge in the patient's hand. From ½ to 1 milliampère of current is passed through the needle for a minute or two. Repeated applications may be necessary to destroy a single vessel. The treatment may result in scarring. To avoid scarring use a very fine needle and do not attempt too much at one sitting. The galvanocautery and fulguration are sometimes used.

The beta rays of radium have been utilized in the treatment of longstanding telangiectasia but it requires considerable treatment to effect the required degree of obliterative endarteritis. For obvious reasons such treatment is contra-indicated.

Refrigeration (solid carbon dioxide; CO_2 snow) as originated by Pusey, if carefully employed is capable of producing very satisfactory results. *X*-ray skin is exceedingly sensitive to this treatment so that the first applications should be very mild. Place the hard pencil of snow firmly against the skin and hold in place for not more than one or two seconds. The time of exposure may be increased cautiously to ten seconds or more. Refrigeration that will do no more than effect an erythema or a bulla of the normal skin may produce deep ulceration and disfiguring scars in *x*-ray skin. It is well to keep this fact in mind. The drums or tanks of liquid carbon dioxide are the same as those employed in connection with soda fountains, and may be obtained through the druggist or direct from the manufacturer. To collect the snow, roll an ordinary blotter into the shape of a tube about four inches in length with a lumen that will fit snugly over the outlet of the drum. A new drum usually contains a little water which may interfere with the production of snow. To get rid of the water place the drum over a chair at an angle of 80 or 90 degrees, open the valve a little and allow the water to escape. Now place the blotting-paper tube over the outlet, plug the distal end with cotton, wrap a towel around the tube and neck of the drum and wind a heavy flannel bandage over the whole. Then tilt the drum to an angle of about 40 degrees and open the valve freely. The carbon dioxide escapes as a gas which has a temperature below zero. The snow is formed by the freezing of the watery vapor of the atmosphere. Gas is allowed to escape until a loud crackling noise is heard. Removal of the blotting paper reveals a firm crayon of snow. The blotting paper method (originated by Tousey) is perfectly satisfactory for occasional use. Refrigeration has the disadvantage of being painful.

Another method of treating telangiectasia—a method of considerable promise and one that is painless, consists of the administra-

tion of ultraviolet rays by means of the Kromayer lamp (Axman and others). Full current is used, the quartz front is pressed firmly against the skin for purposes of dehematization and an exposure of five seconds given. If the skin is not unduly sensitive the exposures are increased gradually to one and then to three minutes. Exposures of five and even ten minutes have been given but three minutes is the usual amount. This produces a bullous reaction that heals in from one to two weeks. Treatments are given at intervals of from two to four weeks. Normal skin around small areas can be protected by employing a quartz front-piece of suitable size or by using a piece of black cloth containing a hole of the right size.

At the best, telangiectasia is a very difficult condition to master and it is only by perserverance and the careful employment of the enumerated methods of treatment that even partial success can be attained.

Atrophy.—There is little if anything that can be done for this sequela. Rarely there is spontaneous improvement. Persistent massage may accomplish some good.

Dry Skin.—Dry skin is due in part at least to lessened activity of the coil glands and sebaceous glands. Unless these appendages have been totally destroyed there is likely to be some regeneration. The treatment for such skin is protection from the cold and the free application of oily emulsions, creams and ointments.

Alopecia.—There is no successful treatment for *x*-ray alopecia. Wigs, of course, can be used.

Keratoses.—The treatment of *x*-ray keratoses and *x*-ray cancer will be found in Chapters XXX and XXXIII.

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CHAPTER XVI.

PATHOLOGICAL HISTOLOGY OF RADIODERMATITIS.

MOST of the systematic histological study has been made on small animals whose skin, particularly the epidermis, is somewhat different from that of man. The findings, however, compare favorably with those obtained in similar work on the human skin. Colwell and Russ review the work thoroughly up to 1914.

RADIUM.

Guyot exposed white mice, at one sitting, to a quantity of radium rays sufficient to produce a second-degree reaction. Clinically, toward the end of the first week there was erythema followed in a day or two by desquamation. The hair began to fall by the end of the second week. During the third week there was edema, denudation, exudation and crusting. Ulceration and crusting continued until the third month. Healing occurred in the fourth month. There was almost complete regeneration of hair within six months. It may be interjected here that the hair follicles of human skin never regenerate after second-degree reactions. The skin of small animals tolerates comparatively large doses and shows greater ability to repair damage than does human skin.

Microscopical Examination.—As early as the third day there was a proliferation of epithelium and an increase in connective-tissue cells, together with dilated vessels. Epithelial proliferation continued until the tenth day after which the cells degenerated; the entire thickness of the epidermis was destroyed by the tenth day. In the meantime the cutis had become thickened by edema, the connective-tissue elements had increased markedly and there were a few scattered leukocytes. In the next two weeks the picture was much the same with the exception of an acanthosis at the periphery of the ulcer with epithelial downgrowths extending deep into the derma. The rete prolongations, together with keratohyaline degeneration and cell nests, produced a picture suggestive of epithelioma. During the second month there was considerable infiltration of the derma and the edema became more intense. The connective tissue then degenerated and the cutis became a mass of granulation tissue. On the ninety-fifth day, after clinical recovery, the marginal epidermal hypertrophy and the downward prolongations were still present. The cutis was more compact than normal, elastic fibers were present and bloodvessels were numerically decreased. The hair follicles were beginning to regenerate. The arrectores showed very little change. At the end of five months the

of appendages. Dominici was impressed with the resemblance to a rapidly growing fibroma.

Halkin employed young pigs because the skin resembles that of man. The strength of the application was sufficient to produce superficial

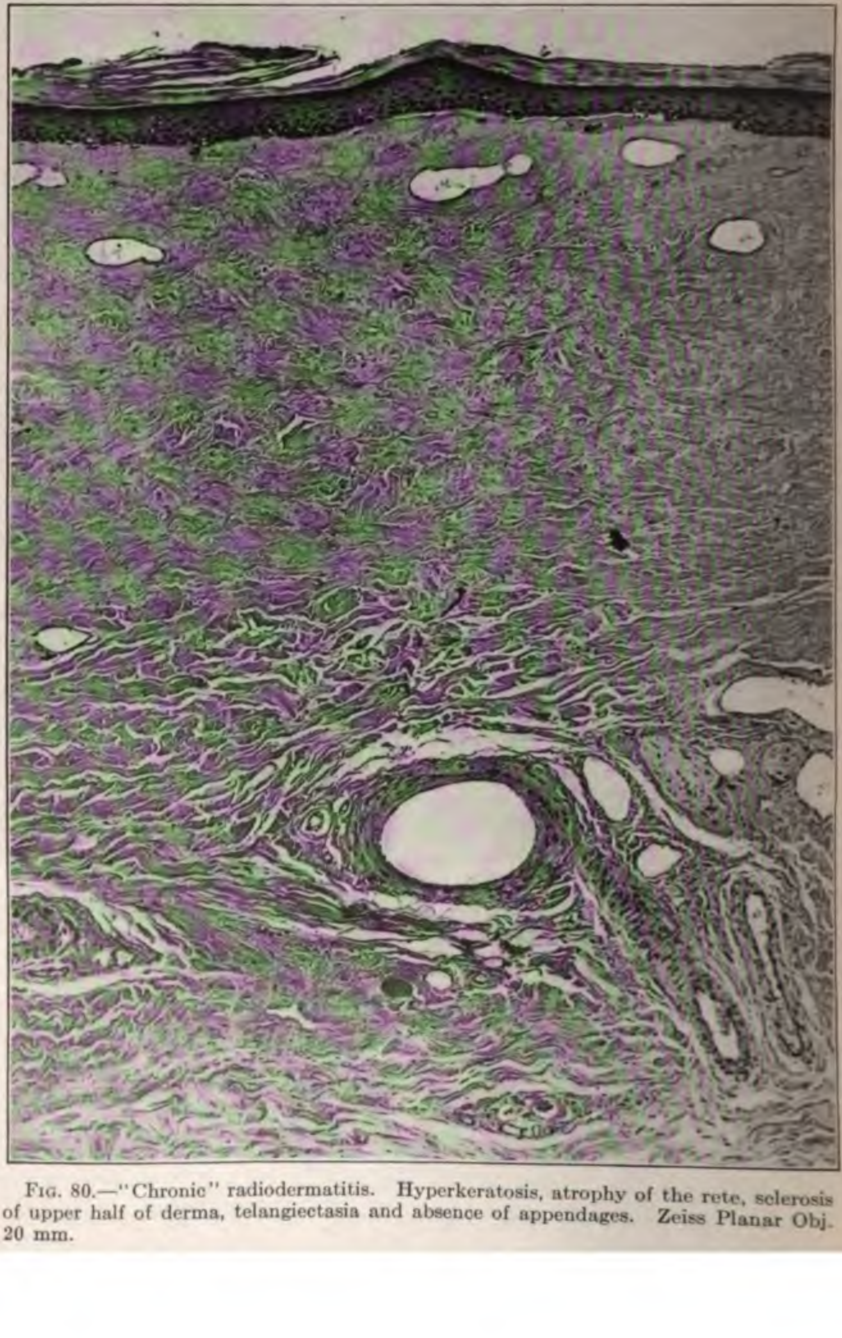

FIG. 80.—"Chronic" radiodermatitis. Hyperkeratosis, atrophy of the rete, sclerosis of upper half of derma, telangiectasia and absence of appendages. Zeiss Planar Obj. 20 mm.

Dominici studied the irradiated skin of guinea-pigs. Clinically, erythema developed in ten days, ulceration in about three weeks and healing occurred in six weeks. Microscopically, at the end of ten days, the epidermis showed intercellular edema with changes in the protoplasm and nucleus. This was followed by desquamation. In addition to the ordinary signs of inflammation in the derma, Dominici noted that the cutis was composed largely of young connective-tissue cells. The vascular walls were reduced to stellate cells whose prolongations connected with the fibroblasts and the endothelial cells. The non-striated muscle tissue could hardly be distinguished from the connective tissue. The process seemed to be embryonic and angiomatous and was called the stage of embryonic regression. The final stage, at the end of six or seven months, was fibrosis. The young connective-tissue cells were converted into parallel bundles of dense fibrous tissue. Elastic tissue seemed to be increased. There was no regeneration nor new formation

FIG. 79.—A small *x*-ray keratosis. Photograph shows hyperkeratosis, acanthosis, dyskeratosis, loss of rete pegs, disorganization of basal-cell layer, degeneration of papillary body, dilated capillaries and absence of appendages. Zeiss Obj. 8 mm. Comp. Oc. 4.

Fifth Day.—Epidermis.—The cell nuclei were unstained. Chromatin débris was found between the cells. There was both intracellular and intercellular edema. *Derma.* The nuclei of the connective-tissue cells had disappeared. There was considerable nuclear débris. Small hemorrhages had occurred. The muscular tissue was well preserved. All the vessels, even those of the subcutaneous tissue, were degenerated. In the latter location there were numerous eosinophiles. The epithelium of the hair follicles showed marked degenerative alterations.

Seventh Day.—The epidermis had disappeared in the center of the irradiated area. At the periphery the epidermis was thickened and epithelial downgrowths extended into the cutis. The cells in this part of the epidermis showed no marked changes. The eosinophiles in the subcutaneous tissue had disappeared.

Eleventh Day.—The conspicuous features were deep and extensive downgrowths of the rete at the periphery of the denuded area, with keratohyaline degeneration, cell nests and whorls very similar to those seen in metastatic epithelioma. The vessels, even the larger ones of the deep cutis and subcutaneous tissue, depicted a profound disintegration of endothelium, to such an extent as to practically destroy the cutaneous circulation.

Fourteenth Day.—There was almost total destruction of the connective-tissue elements. The downgrowths of epidermis were even more marked than on the eleventh day. This was the last specimen examined.

X-RAYS.

Very little experimental histological work has been conducted in connection with the *x*-rays, especially in the acute reactions. Most of the examinations have been made on human skin in cases of chronic radiodermatitis, *x*-ray sequelæ, or *x*-ray cancer.

Darier, in collaboration with Oudin and Barthélemy, studied the roentgenized skin of guinea-pigs in 1897. They lay stress on the marked thickening of all the layers of the epidermis, fibrosis of the cutis and complete destruction of the appendages.

Gassmann devoted especial attention to the vascular changes in ulcerative radiodermatitis of rabbits. He observed marked vacuolization of the muscular coat. The endothelium was swollen and proliferated to the point of complete obliteration. The elastica was fragmented. The same endothelial changes were noted in the lymphatics.

Scholtz, using pigs, examined the irradiated area seven days after exposure at which time there was no macroscopical evidence of reaction. The stratum corneum was less compact than normal, the prickle-cell layer was fused, presenting a somewhat homogeneous appearance. The individual cells were vacuolated, the nuclei broken up and the

staining quality was poor. The corium showed edema and other simple inflammatory changes. The endothelium was degenerated.

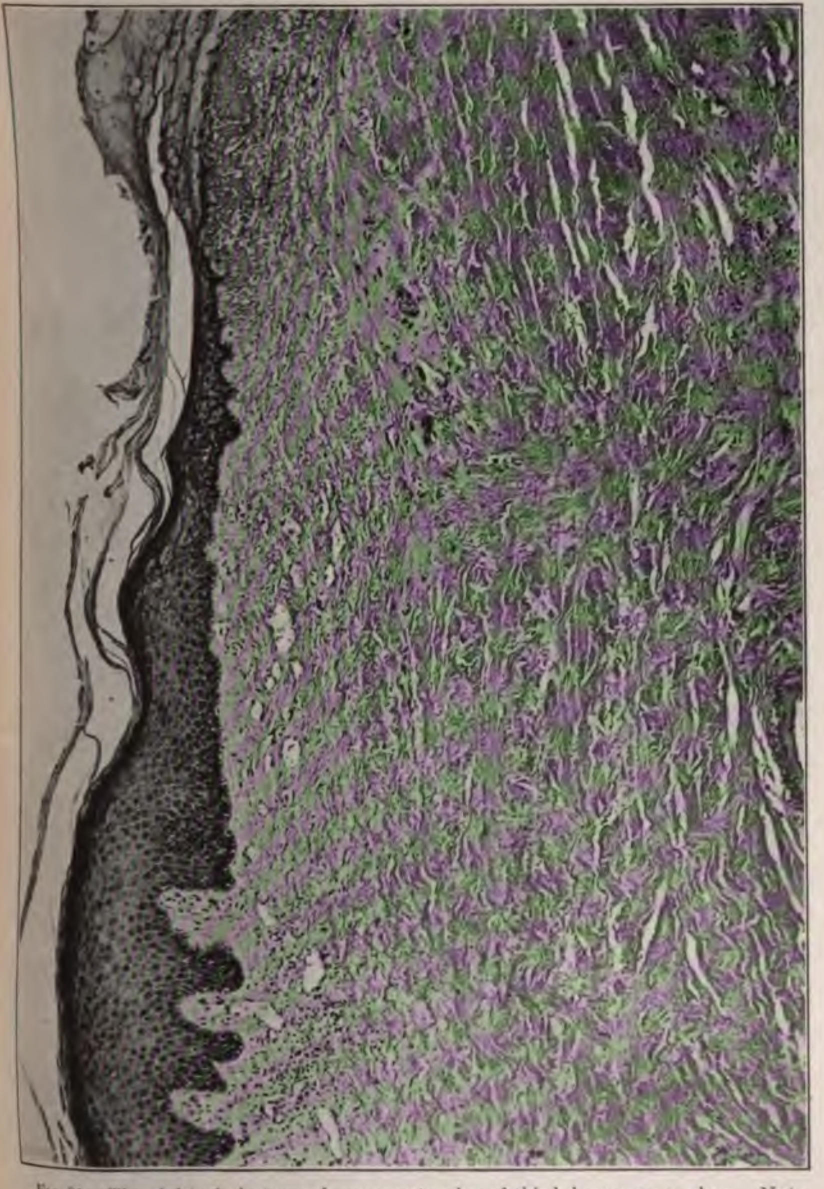

FIG. 81.—The right of photograph represents edge of third degree x-ray ulcer. Note the gradual loss of epidermis. A little farther from the ulcer, toward the left of the picture, the epidermis becomes increasingly hyperplastic. On the right side of the picture the collagen of the epidermis shows considerable degeneration. Note the vascular dilatation and absence of infiltration. Zeiss Planar Obj. 20 mm.

Tissue was examined after clinical ulceration had become manifest. The superficial epidermis—stratum corneum, lucidum, granulosum—had disappeared, the space being occupied by pus cells, débris and bacteria. The bloodvessels were degenerated and there were marked alterations in the fibrous tissue. The elastic tissue was unaffected.

Rowntree lays especial emphasis upon the hypertrophy of the epidermis in areas receiving small amounts of x-rays and at the periphery of severe reactions, as observed in guinea-pigs and rabbits.

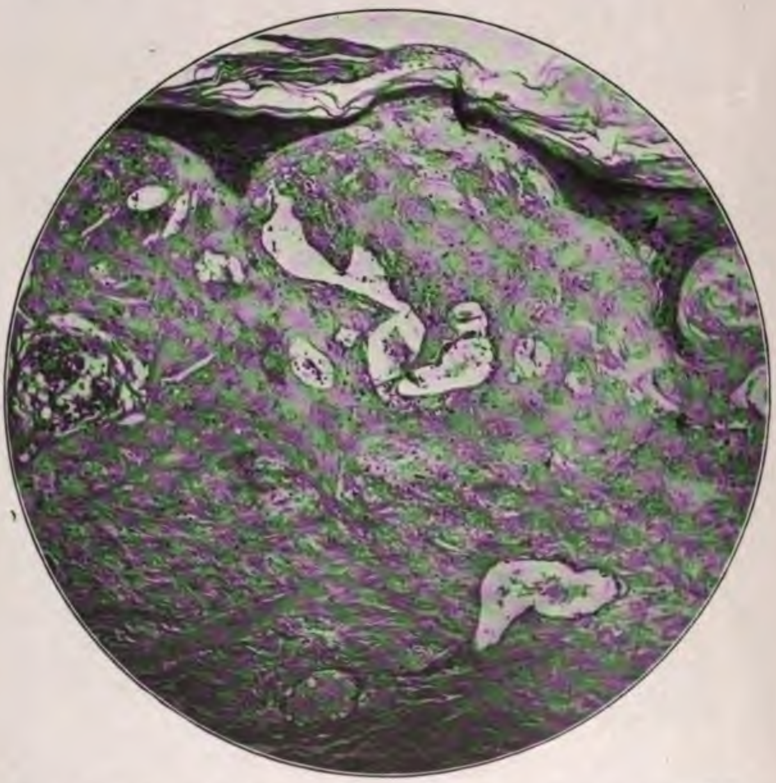

Fig. 82.—"Chronic" radiodermatitis. The collagen is badly degenerated, the vessels are enormously dilated, and the epidermis in places has almost disappeared. Clinically, there were vesicles covered with a thickened horny layer and exudation from under the scale. Zeiss Obj. 8 mm. Comp. Oc. 4.

Human Skin.—Clunet relates a case of chronic hypertrophic radiodermatitis produced by repeated filtered x-ray exposures over a period of several months. There was no preliminary or preceding acute reaction. Clinically the eruption consisted of a low-grade inflammation with perceptible thickening of the skin. Histologically the feature of special interest was the acanthosis, the epidermis being composed of forty layers of cells.

Thies exposed his own skin to radium and removed a section for microscopical study on the tenth day at which time there was no

FIG. 83.—"Chronic" radiodermatitis. Acanthosis, with downgrowth of epidermis, degeneration of derma and very marked dilatation of bloodvessels and lymphatics. Zeiss Planar Obj. 20 mm.

clinical reaction. He noted ordinary inflammatory changes in the derma. The epidermis was slightly thickened, the cells stained poorly, the regular arrangement of the basal-cell layer was interrupted and there was an invasion by leukocytes of the lowermost part of the epidermis.

Unna made a very exhaustive histological study of four cases of chronic, ulcerative roentgen dermatitis, but as usual, it is difficult to follow him through the mass of detail. He found both atrophy and hypertrophy of the epidermis, the latter usually situated at the periphery of the ulcer, with downgrowths into the cutis and a tendency for the cells to become cornified. In the corium he emphasizes the marked intercellular edema, basophilic degeneration of collagen and the final very dense structure of the connective tissue. He found the usual vascular changes and atrophy of the appendages. Hypertrophy of the smooth muscles was noted.

Linser, during the *x*-ray treatment of a case of lupus, studied the irradiated tissue at intervals of four, eight, ten, twenty and thirty days. The first change observed consisted of swollen endothelium leading to thrombosis, and a perivascular infiltration of leukocytes. This was followed by a degeneration of the walls of the vessels and marked inflammatory changes in both the derma and epidermis. The final result was complete repair. Linser is of the opinion that the epidermis is not directly nor permanently affected regardless of the amount of irradiation.

Charles J. White, working in collaboration with C. A. Porter, made a careful histological examination of numerous pieces of tissue removed from an area of chronic radiodermatitis, the specimens representing the various stages of evolution from *x*-ray skin to epithelioma. White was considerably handicapped by being given stained specimens so that he was unable to obtain the advantage of various staining methods. It is unfortunate that he did not attempt a summary of his splendid work as the mass of histological detail is bewildering and represents almost every known phase of epidermic deviation from the normal. The cellular, vascular and protoplasmic alterations were marked and varied. Many of the sections studied represented well-developed metastatic epitheliomata.

There was one particularly interesting slide in Porter's series examined by Mallory and Wright, taken from a growth subsequent to the removal of a probable ulcerated *x*-ray epithelioma. The slide showed an enormous, oval, cellular mass sharply outlined and limited by dense connective tissue. The mass was composed of rapidly growing, young connective-tissue cells and a small number of thin-walled bloodvessels. The individual cells were separated by collagenous fibrils and, together with these fibrils, were formed into small bundles which ran in every direction. This picture suggests the stage of embryonic regression mentioned by Dominici or a rapidly growing fibroma. Mallory's interpretation was that it represented an unusual reparative process

on the part of badly injured connective tissue. Wright, on the other hand, was inclined to favor the possibility of a spindle-celled sarcoma.

The writer encountered two similar cases. In both instances, following the excision of x-ray cancer, there appeared a dark-red,

FIG. 84.—"Chronic" radiodermatitis, showing marked acanthosis at edge of a third degree x-ray ulcer. Zeiss Planar Obj. 20 mm.

smooth, fairly firm growth which attained the size of a cherry in a few weeks. Under the microscope the tissue possessed the characteristics of angiofibroma and angiosarcoma but the final diagnosis was unusual granulation tissue. The tumors disappeared spontaneously in a few weeks.

The best article on this subject in the English language is that by Wolbach who obtained his material from Dr. Porter. The work includes a careful study of all phases of chronic radiodermatitis, *x*-ray skin, keratoses, ulcers and epitheliomata. The tissue was taken from six cases, the excisions being made under general anesthesia and the tissue immediately placed in Zenker's fluid. A large number of staining methods were employed. It is impossible to give the histological minutæ of this exhaustive study. Every word of the article should be read by those who are interested. Wolbach's excellent summary is herewith given verbatim:

1. "*Changes in the Connective Tissue of the Corium and Subcutaneous Tissue.*—The most conspicuous of the constant changes in the corium are the rarefication immediately beneath the epidermis and the great density of the connective tissue deeper down. The loose-textured connective tissue immediately below the epidermis is best interpreted as imperfect repair of degenerated connective tissue due at first to the direct action of the *x*-rays. The imperfect repair and subsequent degenerations are due most probably to the vascular lesions. The presence of degenerated hyaline collagenous material throughout the depth of the corium must be a direct effect of the rays. That this modified collagenous material represents inert or dead tissue, if such a term may be used in speaking of intercellular substance, is proved not only by the physical appearance and staining reactions, but also by the presence of young connective-tissue cells surrounded by normal appearing collagenous fibrils between the masses of this dense collagenous material. Further proof is furnished by the finding of isolated masses of similar material, identical in appearance and staining, in the granulation tissue below the ulcerations. This diffuse aseptic necrosis of connective tissue and resulting diffuse proliferation of connective-tissue cells is probably directly responsible for the obliteration of blood- and lymphvessels. Repeated exposures to the *x*-rays is in this way accountable for the production of successive deposits of collagenous material, and this is the only satisfactory explanation of the great density of the deep corium. Areas of fibrin in tissues many months after the last exposure to the rays prove that the lesions are slowly progressive. The marked increase of elastic tissue almost constantly found is difficult to account for. That a new formation occurs, may be proved by the association of delicate elastic fibers with new connective-tissue cells. Coarse fibrils present may represent remains from successive crops of connective tissue which have undergone degeneration. The presence of many degenerated fibers suggests this explanation. The question needs more elaborate study.

"Many of the connective-tissue cells in the rarefied corium are of extraordinary size with large-processed nuclei. Many have numerous

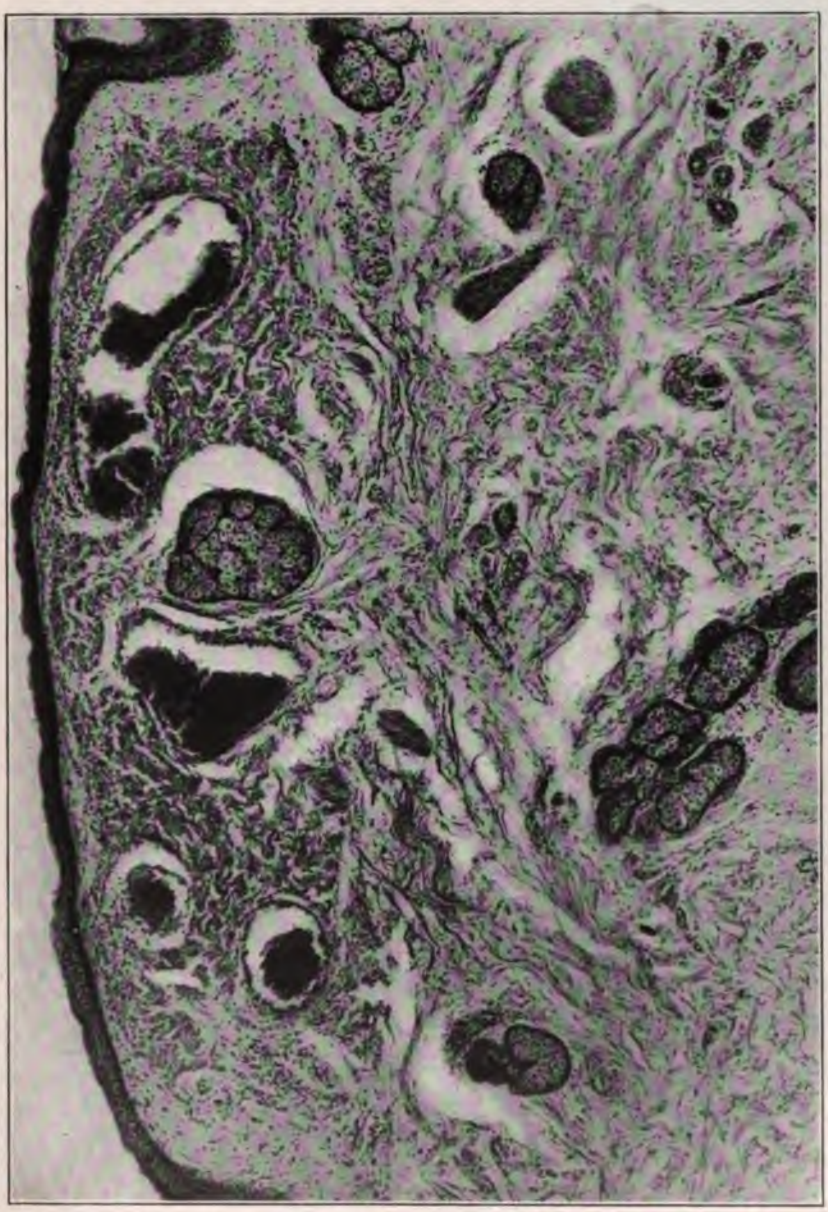

FIG. 85.—"Chronic" radiodermatitis. Atrophy of epidermis, telangiectasia, remnants of hair follicles, sebaceous glands and coil glands. The large dark areas around the greatly enlarged bloodvessels in the upper cutis represent degenerated collagen that stains blue with hematoxylin-eosin. Zeiss Planar Obj. 20 mm.

small nuclei each containing a particle of chromatin. These cells may be distinguished from endothelial cells by the presence of fibroglia fibrils. Apparently they do not form collagenous material. With the methylene blue and eosin stain, protoplasm stains a deep blue. A few are vacuolated. Similar large cells are found in the fat lobules of the subcutaneous tissue, where the fat is undergoing resorption. The interpretation is that these cells are the result of proliferation under conditions of poor nutrition. As they are found only where there is multiplication of connective-tissue cells, they must represent imperfect growth and differentiation.

2. "*Changes in the Smooth Muscle.*—The large size of the arrector pili muscles and the thickness of the nuclei of arteries has led some authors (Unna and Wyss) to speak of the condition as one of smooth muscle hypertrophy. In the present study degenerate changes were always present and the large size of the smooth muscle cells is due to vacuolization (noted by numerous authors) and distention of the cell with hyaline material, the latter easily demonstrable by the phosphotungstic acid-hematin stain. In cases of long duration only atrophic remains of the arrector pili muscles were found, showing that the changes noted are unquestionably degenerative. This degeneration of smooth muscle will be considered again in connection with vessel changes.

3. "*Changes in the Vessels.*—The study of the lymphatics of skin which is the seat of chronic changes, presents extraordinary difficulties when attempted by the methods employed in this study. The unquestionable obliteration of blood capillaries and the extreme difficulty of demonstrating the lymphatics in the tissues studied makes the assumption warrantable that there also has been obliteration of lymphatics.

"The changes in the bloodvessels on the other hand are easily demonstrable. The telangiectases apparently develop from preexisting capillaries, those of the papillæ of the corium. Various stages of dilatation of these capillaries can be seen in connection with other changes, in lesions of varying intensities from different cases. The mechanism of their formation cannot be discovered through histological examination, though obliterative changes in the larger vessels and in the deeper anastomosing capillaries must play a part. Another factor to be taken into consideration is possible traction upon the capillary walls exerted by contracting connective tissue. New collagenous material is frequently laid down between the meshes of older degenerated fibrous tissue and undoubtedly must undergo some contraction before the dense stage is reached. Thrombosis of these telangiectases is common and is usually associated with necrosis of the tissue immediately surrounding as well as of the lining endothelium. Obliteration of capillaries by proliferation of endothelium is a fairly constant finding in most of the cases studied.

"The obliterative changes in the veins and arteries are manifested chiefly i[illegible]crease of connective tissue beneath the endothelium

and in marked thickening of the media. In the arteries there is disappearance of the elastic lamina and a substitution of a thick,

Fig. 86.—"Chronic" radiodermatitis, showing fairly normal distribution of elastic tissue. Zeiss Planar Obj. 20 mm.

irregular band of hyaline collagenous material. The thickened intima is composed of connective tissue with much collagenous intercellular

substance. The endothelium is often composed of swollen and vacuolated cells which occasionally form tufts of cells projecting into the lumen.

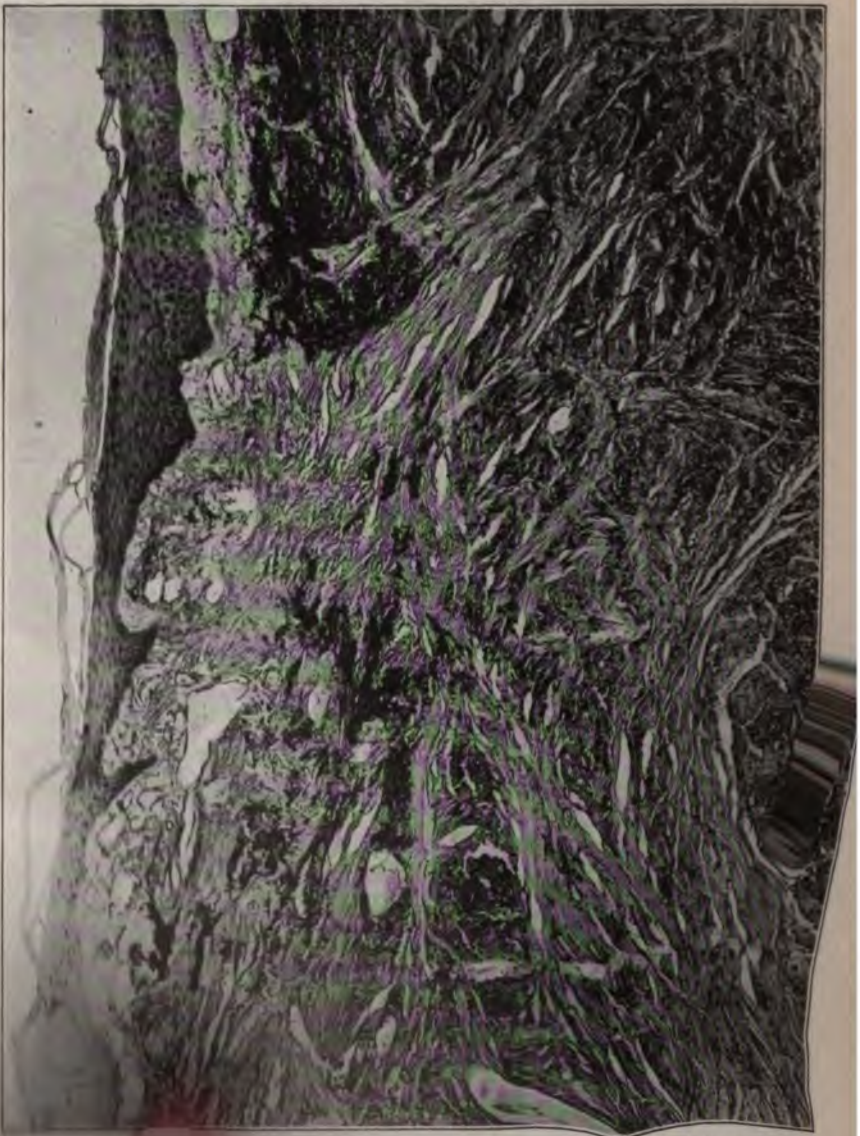

FIG. 87.—[illegible] radiodermatitis, showing clumping of elastic tissue. Zeiss Planar Obj. 20 mm.

The [illegible] of the media is due to an increase of connective tissue. [illegible] f the stains employed it is possible to demonstrate

"The finding of mitotic connective-tissue cells in one case four years after the last exposure illustrates the extreme slowness of this process, as well as its progressive character. In advanced cases of obliterative endarteritis the media is wholly replaced by connective tissue with many large branching fibroblasts. In all of the cases studied obliterative changes have been found in some of the vessels, though normal vessels are usually also found.

4. "*Changes in the Epidermis.*—Except over foci of acute degeneration of the corium, hypertrophy of the epidermis is a constant finding. The hypertrophy in most cases is in the form of a fairly uniform thickening of the epidermis. In other cases there are local more marked hypertrophies taking the form of keratoses and downgrowths. In nearly every case there are numerous areas where the proliferation of epidermis seems unquestionably to be due to disappearance of connective tissue in the corium which has not the power to repair itself. The downgrowth of epidermis is analogous to the growth of the corneal epithelium following an incised wound of the cornea, or even gaping wounds of the cornea such as may be made by plowing beneath the corneal epithelium with a sharp triangular-shaped needle (Glover's needle).

"Extensive undergrowths of epidermis are found in several cases having all of the characteristics of carcinoma with and without evidence of invasion. The cases showing metastatic growths have not been included in this report. Growth of epidermis into thrombrosed telangiectases is unusual and must be interpreted as indicative of increased powers of growth. Generally the epithelial downgrowths are surrounded by zones of dense infiltration of lymphoid and plasma cells, eosinophiles and polymorphonuclear leukocytes. The epidermis where there is evidence of greatest proliferation of the basal layers has a thin horny layer, as if the whole capacity of the epithelium were taxed to preserve its continuity.

"In general the increased thickness of the epidermis and the production of wart-like growths or keratoses and downgrowths is best explained as the result of constant active proliferation called for by the constant production of small defects in the underlying corium."

GENERAL SUMMARY.

There is no essential histological difference between the reactio produced by radium and that caused by the *x*-rays.

The earliest changes are inflammatory and appear to consist of dilatation of the vessels throughout the cutis, including those of th appendages. The endothelium is swollen. The first signs of infiltration are seen in the perivascular lymph spaces. The infiltrating cel are mainly lymphocytes with some young connective-tissue cells. A dermal structures become swollen, the swelling being due ellular [illegible] tracellular edema. The alterations in the epiderm

re secondary and consist of intercellular and intracellular edema and slight acanthosis.

If the reaction continues the histologic evidence of inflammation becomes more manifest. The infiltration ceases to be focal; small round cells become scattered throughout the derma. The lymph spaces and the bloodvessels are widely dilated and congested. Their walls become swollen and the endothelial cells proliferate. The lumina of many of the capillaries are occluded. The appendages are infiltrated, their vessels depict the same changes as do those of the derma, and more or less complete destruction follows edema and degeneration of their epithelial cells.

If the injury is severe the collagen shows distinct evidence of degeneration, often basophilic, staining blue instead of red with hematoxylin-eosin. The vessels undergo degeneration and some are completely destroyed. The muscles may be so altered as to be almost indistinguishable from collagen. Elastic tissue is very resistant but it is likely to be fragmented. Close to the epidermis the fibrous tissue becomes granular and may be replaced by granulation tissue. The destruction of the derma depends upon the degree of injury. In very severe third degree reactions ulceration may extend down to the subcutaneous tissue.

In the profound reactions the infiltration early invades the epidermis. There is a very marked intercellular and intracellular edema, vacuolization, loss of prickles, poor staining qualities, loss of nuclei and disorganization of the basal-cell layer. This is followed by erosion, even to complete disappearance of the epidermis. At the edge of the eroded area and particularly at the margin of chronic ulcers, the epidermis is acanthotic, sometimes to an extreme degree, and there may be irregular downgrowths and keratinization. Tangential sections through such tissue yield pictures suggestive of epithelioma.

The histological findings in chronic radiodermatitis (*x*-ray skin) are complex and depend upon the degree of injury and the completeness of repair. In two instances clinically normal skin was obtained three years subsequent to a first degree radiodermatitis. The histological examination was negative. In another instance there was clinical and histological evidence of telangiectasia but otherwise the examination was negative. In still another instance there was clinical atrophy without telangiectasia two years subsequent to a mild first degree reaction. Histologically, with the exception of a reduction in the size of the rete pegs, the epidermis was normal, but there was a slight sclerosis and retraction of connective tissue. The vessels seemed to be numerically diminished and most of those present were somewhat dilated. The elastica was normal. Coil glands, sebaceous glands and lanugo hair follicles were present but they were diminished in number and size.

A very common late picture, following complete repair of a severe injury, is a thinned epidermis with loss of pegs and a sclerotic, compact

connective tissue. There is likely to be a paucity of vessels and those present are apt to be markedly dilated. There is usually complete absence of all appendages. The elastic tissue may be normal, fragmented, increased, or collected in masses. There may be an interferance with normal keratinization as evidenced by hyperkeratosis and, at times, parakeratosis.

In instances where the tissue has been injured beyond the possibility of complete repair, the papillary body and the subpapillary layer is usually edematous and the collagen badly degenerated. This part of the derma may fail to take the stain. In places the degenerated connective tissue may stain blue with hematoxylin-eosin (basophylic degeneration). Such tissue may be granular or the bundles and fibers may be fairly well preserved. Occasionally one encounters large masses composed of swollen fibers and granular débris. This tissue stains blue with hematoxylin-eosin and also takes the elastic tissue stains. It is probably degenerated elastic tissue—elacin. The elastic tissue varies from normal to complete absence; or it may be fragmented or found only in dense masses. Bloodvessels are either sparsely distributed or widely dilated. There is usually very little infiltration. Over such areas the epidermis may be atrophic, badly degenerated, dyskeratotic or hypertrophic. The tinctorial qualities are poor, there is an absence of nuclei, the cells are edematous and degenerated, and there is usually a marked hyperkeratosis. This is the histological picture of a clinical keratosis and represents one way in which epithelioma develops. As Wyss has observed, *x*-ray epithelioma is the first experimental cancer. Unna, Ribbert, Wyss and especially Wolbach aver that it is primarily the progressive vascular changes and the consequential alterations in the cutis that cause the epidermis to assume proliferative properties in order to preserve its integrity. The cells, living in a changed environment acquire independent powers of growth at the expense of differentiation and, also at the expense of other living tissue—a gradual development of malignancy. As stated by Wolbach, "the acquisition of malignant powers is completed during years of active proliferation accompanied by progressive impairment of nutrition. This much we have microscopic evidence for, and the hypothesis that the former is a direct sequence of the latter seems justifiable. Finally, it is not far removed from von Hansemann's hypothesis of tumor origin, that of anaplasia wherein the power of growth is attributed to reversion to the stage of proliferative function at the expense of differentiation."

Unna and others think that telangiectasia is due to retraction of the connective tissue of the derma. In this connection, however, and contrary to general opinion, irradiation is likely to profoundly influence the function and distribution of elastic tissue. Most investigators believe that the cutaneous vascular apparatus is the part primarily and most profoundly injured. This is quite likely so but it must be remembered that the action of *x*-rays and radium rays is on the indi-

vidual cell so that the final result is the combined effect of irradiation on the cells of all the tissues with subsequent successful or abortive attempts at repair. Histology does not demonstrate the cause of the reaction. Cytology and biochemistry afford a reasonable hypothesis (Chapter XIII).

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The author is especially indebted to the works of Colwell and Russ (Radium, *X*-rays and the Living Cell, G. Bell and Sons, London, 1915) and Wolbach, S. B. (Pathological Histology of Chronic *X*-ray Dermatitis and Early *X*-ray Carcinoma, Jour. Med. Research, 1909, xvi, n. s., p. 415) in compiling this chapter.

CHAPTER XVII.

IDIOSYNCRASY.

In spite of the fact that this difficult subject has been under discussion for many years there is as yet no absolute unanimity of opinion. In 1911 Arcelin, in an endeavor to obtain a representative opinion, questioned thirteen leading roentgenologists. Seven, among whom were Bergonié, Bordier, and Noiré, thought that idiosyncrasy did exist while six, among whom were Belot, Bordet, Darier, Guilleminot, and Kienböck, held the opposite opinion. Twelve years ago (1908) the writer obtained the opinions of the leading American roentgenologists on the question of idiosyncrasy. A few men, among whom were Piffard and Caldwell, were beginning to believe that idiosyncrasy was largely technical rather than biological. Most of the men, however, were firmly convinced that true idiosyncrasy of a pronounced degree was of fairly common occurrence. In February, 1920, the following American roentgenologists and dermatologists were asked if they believed that there was an idiosyncrasy to the *x*-rays:

W. A. Pusey
G. E. Pfahler
H. H. Hazen
H. K. Pancoast
Geo. C. Johnston
J. F. Schamberg
L. G. Cole
O. S. Ormsby
Howard Morrow
D. R. Bowen
Fred Wise
W. D. Witherbee
R. D. Carman
Russel Boggs
H. W. Dachtler
P. M. Hickey
W. H. Stewart
Samuel Stern
John Remer
M. M. Roland
M. F. Manges
G. W. Wende
Howard Fox
J. T. Case
J. G. Van Zwaluwenburg
A. M. Cole
F. H. Baetjer
H. M. Imboden
C. A. Simpson
E. S. Lain
Leopold Jaches
Percy Brown

The replies showed a surprising and unexpected unanimity of opinion. A few of the men answered the question directly and averred that there is no true idiosyncrasy. The majority recognized a distinct variation in susceptibility in different persons but of a degree too small to be called true idiosyncrasy. While they had never encountered a case of undoubted true idiosyncrasy of severe type yet such a phenomenon, while uncommon or even rare, was a probability.

A few of the men replied positively in the affirmative. Pancoast found persons who for no discoverable reason were unable to stand nearly the amount of *x*-rays tolerated by the majority of patients.

Baetjer tells of a patient who was exposed for a few seconds to a tube placed at a distance of 24 inches, the result being a dermatitis. He also relates the case of an *x*-ray technician who exposed his hand to the *x*-rays several times daily for a number of years without visible injury to the skin. Morrow, L. G. Cole, and Case believe they have seen examples of true idiosyncrasy. Case tells of three patients who reacted violently to a carefully measured dose of 3X (about ⅓ erythema dose, unfiltered).

The same question, this time in reference to radium, was sent to H. H. Janeway, W. S. Newcomet, Howard Kelly, Isaac Levin, Douglas Quick, and F. E. Simpson. The replies indicate a firm belief in variations of susceptibility but no true idiosyncrasy.

In the early days of *x*-ray work unexpected reactions were extremely common and the literature of that time contained innumerable reports of severe reactions following a technic that caused no untoward results in other individuals. Idiosyncrasy at that time was an accepted fact and its occurrence was thought to be common. Certainly it was the easiest way to explain the mysterious reactions. Idiosyncrasy was questioned first in Germany probably by Kienböck and in France and the doubt was contemporary with the advent of such methods of dose estimation as devised by Sabouraud and Noiré, Kienböck, Holzknecht and others. With the use of these radiometric methods of measurement unexpected reactions occurred much less frequently. In France, and later in England, thousands of cases of ringworm of the scalp were treated with very few instances of reaction or permanent alopecia. Inasmuch as such treatment necessitates extreme accuracy, on account of the slight margin of safety, the relatively few reactions in such a large number of cases caused no little surprise and comment. In the meantime European roentgenologists were beginning to apply massive but carefully measured doses in the treatment of both cutaneous and deep-seated affections and they found, as technic improved, that unexpected reactions became less frequent. The use of the term idiosyncrasy has decreased in about direct proportion to improvement in technic and increase in therapeutic and biologic knowledge. Today it is uncommon to encounter unexpected reactions that cannot be explained by faulty technic, erroneous calculations, avoidable or unavoidable accidents, poor judgment or other ascertainable causes.

It is well known that the skin of various persons and even that of the same individual will react differently under changed conditions. These various factors will now be discussed separately.

Age.—The skin of any given part of an aged individual is markedly less sensitive than that of an infant. There is also a noticeable difference between adults and children.

Sex.—The skin of females, as a rule, is slightly more sensitive than that of males.

Texture.—A thin, fine skin is more susceptible than is a thick, coarse skin.

Circulation.—A skin that is pale or anemic will react less readily than one that possesses a good circulation. The most sensitive skin in this respect is one that is hyperemic or congested.

Simpson obtained reactions in the skin of the anterior neck in women who had been applying ice for the relief of hyperthyroidism. The dose was 3½ Hampson units filtered. The same patients, without the ice applications, failed to react to 5 Hampson units. Cold applications produce localized anemia, and an anemic skin will tolerate comparatively large amounts of irradiation (see page 270), while hyperemic skin is comparatively supersensitive. It is possible, therefore, that it was the congestion subsequent to ice application that produced the hypersensitiveness in Simpson's patients. Codman mentions cutaneous vasomotor irritability and congestion or hyperemia resulting from such applications as the high-frequency spark, as causes for lessened resistance to irradiation. Sunburn, ultraviolet light, heat and various other physical agents may effect a temporary hypersusceptibility. Heidingsfeld found the skin in a case of dermatitis hiemalis abnormally sensitive.

Auer and Witherbee, working with rabbits, increased the resistance of the tissues to destructive doses of *x*-rays by sensitizing the animals to a foreign proteid (horse serum). Hecktoen, working with dogs, made a somewhat similar observation. The inference is that the anaphylactic antibody anchored to the tissue cell increases the resistance of the cell to destructive doses. Control animals and sensitized-reinjected animals, the latter having antibodies in the circulating blood, were considerably more susceptible to roentgenization.

Color.—Blonds are usually more susceptible to irradiation than are brunettes. The negro skin is the most resistant.

Location.—Topographically there is a very pronounced variation in susceptibility. Insofar as concerns a visible reaction the least sensitive part of the body seems to be the scalp. The face is probably the most sensitive part. The extensor surfaces are more resistant than are the flexor surfaces. The flexures are very sensitive. There are important exceptions to these rules. The thin skin over the extensor surfaces of the articulations reacts more readily than does that of the immediate vicinity. The palms and soles, on account of the thickened horny layer are less sensitive than such flexures as the anterior neck and the axillæ. The mucous membranes are perhaps more sensitive than the most sensitive normal skin.

Irritants.—Irritating and stimulating chemicals applied to the skin before, during or shortly after irradiation, will markedly enhance the effect. Such chemicals as iodine, chrysarobin, sulphur, mercury, tar, pyrogallic acid, salicylic acid, iodoform, etc., if employed in strength and at about the time of irradiation, may create a hypersusceptibility of an exceedingly high degree. Susceptibility caused by local applications will disappear in from one to four weeks depending upon the strength and character of the application and the amount of reaction

provoked. Hypersusceptibility will prevail during a chemical dermatitis and for a week or two subsequent to its complete disappearance. If no visible reaction follows a chemical application the skin will react normally to irradiation in a week or two. If irritating chemicals have been applied to the skin for a long period but without visible reaction, the skin is likely to be hypersensitive for at least two weeks after the local applications have been discontinued. Solutions and especially ointments containing even small quantities of irritants, if employed at the time of irradiation, are likely to enhance the effect.

After irradiation the skin is hypersensitive to irritants, the degree and duration depending upon the amount of radiation applied. Skin that has reacted to irradiation is very sensitive for a month or two and may remain sensitive to strong irritants for a number of years. Skin that has been subjected to fractional or massive treatment without visible injury will tolerate irritants of mild to moderate strength in about a month. Even strong irritants may be tolerated at this time, but the skin is likely to remain rather sensitive to such agents for a variable time.

ILLUSTRATIVE CASE REPORTS.

CASE 1.—A patient with confluent, inflammatory psoriasis of the palms and soles. Erythema doses were applied to the affected parts at monthly intervals for three months. The palms, soles and dorsal surfaces of the hands received the same amount of irradiation. There was a slight first degree reaction after each application. The eruption underwent involution subsequent to the first treatment but immediately relapsed. The second and third treatments were of no benefit. Three weeks after the last exposure the patient soaked gauze in a mixture of equal parts of castor oil, balsam of Peru and oil of cade and wrapped the hands in the gauze upon retiring. He was awakened during the night by a burning sensation whereupon more of the mixture was added to the bandages. An hour or two later the burning pain being very intense the bandages were removed and it was noticed that the hands were red and swollen. The patient was seen the next day at which time the hands were markedly swollen, tense and painful. The edema was cutaneous and subcutaneous. The skin was erythematous, but there was no vesiculation, excoriation nor ulceration. The symptoms endured for several months. The feet, which had received the same amount of radiation but to which the mixture had not been applied, remained normal. The patient was seen two years later at which time he received *x*-ray treatment for pruritus ani. The skin of the palms was slightly atrophic, dry and there were a few dilated capillaries. The soles were normal. The patient had occasional attacks of psoriasis.

CASE 2.—An epithelioma situated in the right eyebrow of a woman was given one application of *x*-rays consisting of H2 S. D. This was followed by a mild second degree reaction which healed in a month. Two months after the treatment a single application of a 10 per cent. ointment of ammoniated mercury was followed within a few hours by erythema, burning pain and superficial edema. The inflammation subsided in two weeks. The same ointment when applied to another part of the body failed to provoke a reaction.

CASE 3.—A woman received three erythema doses of filtered *x*-rays to the breast at intervals of six weeks. Each application consisted of H2½ S. D. filtered through 3 mm. of aluminium. Each treatment was followed by a first

ιick, adherent slough—a third degree radiodermatitis due to the
›n of irritating chemicals on skin that had received two erythema
›ns of *x*-rays (Fig. 89).

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to direct sunlight or to extreme cold.

uent Irradiation.—Skin that has been irradiated but not
ıjured does not appear to acquire a susceptibility to further
›n providing that accumulation is avoided. If the skin has
ıred as manifested by a reaction or by sequelæ it is likely to be
ıdily affected by subsequent irradiation. This has been
noted by Bergonié. The acquired susceptibility may be
, persistent or permanent depending upon the amount of
ıd the ability of the tissue to repair the damage. In this
›n the following case is of interest.

. An epithelioma of the ear, involving the cartilage had received
roentgenization intermittently over a period of two years. The
not improve so the treatment was discontinued. One year later,
:ime there was no visible atrophy or other sequelæ, an intensive dose
consisting of H2 S. D. was administered. This resulted in a mild
gree reaction which disappeared in six weeks. Two weeks later a
tic dose of H1½ S. D. was applied; a first degree reaction followed.
nths subsequently there was recurrence of the epithelioma. The
excised, the excision including a portion of the cartilage. One week
le the wound was granulating, H2 S. D. was applied. This resulted
degree reaction which required one year to heal.

the work was done eight years ago when technic was not as
:loped as at present, yet it is doubtful if a technical error was
: of the injury. A more reasonable interpretation is that the
l been injured beyond complete repair as a result of previous
›n. Also that the last treatment was administered at a time
:y vascular granulation tissue was present, before the tissue
recovered from surgical traumatism and when cartilage,
s a low resistance, was exposed to the full force of the treat-

ulation.—Experience has taught that it is not safe, in order to
mulative effects, to repeat intensive treatments in less than
:ks. The interval will depend partly upon the size of the dose
ımediate effect on the skin. A three week interval may do for

degree reaction. Three months after the last irradiation the skin showed slight atrophy and loss of hair. An ointment containing 4 per cent. salicylic acid, 10 per cent. oil of cade and 10 per cent. ammoniated mercury was applied to the affected part. After two or three applications the skin became inflamed but the ointment was continued. In less than two weeks a very painful indolent ulcer resulted. The ulcer was indistinguishable from a third degree radiodermatitis. It healed in six months. The end-result was scarring, atrophy and telangiectasia.

Case 4.—A woman with psoriasis was referred by the late Dr. George T. Jackson for roentgenization. Dr. Jackson had directed the patient to apply a 2 per cent. chrysarobin ointment to the lesions of the left arm. Only the lesions on the right arm were to receive x-ray treatment. The lesions of both arms were given $H\frac{3}{4}$ S. D. The lesions that received both x-ray and chrysarobin reacted vigorously—erythema, edema and vesiculation; the others disappeared without reaction.

Fig. 89.—A third degree radiodermatitis due to irritating applications applied during a first degree reaction. Note separation of slough at edge of ulcer.

Case 5.—Mr. J. W. Referred by Dr. H. M. Kalvin, of Brooklyn. This patient had a sarcoma nodule on the flexor surface of the right forearm and two similar nodules in the right popliteal space. Each area (lesions and considerable normal skin) was given $H2\frac{1}{2}$ S. D., 3 mm. of aluminium. This was followed by a first degree reaction which subsided in two weeks. The lesions were much improved. Six weeks after the first treatment the same dose was again administered to each area. This treatment was followed by a first degree reaction. The patient applied ointments containing lysol, balsam of peru and scarlet red to the popliteal space but not to the arm. The erythema of the arm soon disappeared. The area in the popliteal space became intensely red, hard and painful. The hardened area developed into an indolent ulcer

with a thick, adherent slough—a third degree radiodermatitis due to the application of irritating chemicals on skin that had received two erythema applications of *x*-rays (Fig. 89).

Attention is called to the fact that not only is the irradiated skin less resistant to irritation but strong irritation applied to such skin may result in injury that is clinically identical to radiodermatitis and which may affect *x*-ray sequelæ. It is unusual for this loss of resistance to last more than a few months excepting where the skin has been very badly injured.

Skin that has been badly damaged by irradiation behaves much as does sailors' skin and xeroderma pigmentosum. The excessive dryness favors eczematization. Ulceration is likely to follow traumatism, and exposure to direct sunlight or to extreme cold.

Subsequent Irradiation.—Skin that has been irradiated but not visibly injured does not appear to acquire a susceptibility to further irradiation providing that accumulation is avoided. If the skin has been injured as manifested by a reaction or by sequelæ it is likely to be more readily affected by subsequent irradiation. This has been especially noted by Bergonié. The acquired susceptibility may be transient, persistent or permanent depending upon the amount of injury and the ability of the tissue to repair the damage. In this connection the following case is of interest.

Case 6. An epithelioma of the ear, involving the cartilage had received fractional roentgenization intermittently over a period of two years. The lesion did not improve so the treatment was discontinued. One year later, at which time there was no visible atrophy or other sequelæ, an intensive dose of *x*-rays consisting of H2 S. D. was administered. This resulted in a mild second degree reaction which disappeared in six weeks. Two weeks later a prophylactic dose of H1½ S. D. was applied; a first degree reaction followed. Eight months subsequently there was recurrence of the epithelioma. The lesion was excised, the excision including a portion of the cartilage. One week later, while the wound was granulating, H2 S. D. was applied. This resulted in a third degree reaction which required one year to heal.

While the work was done eight years ago when technic was not as well developed as at present, yet it is doubtful if a technical error was the cause of the injury. A more reasonable interpretation is that the tissue had been injured beyond complete repair as a result of previous irradiation. Also that the last treatment was administered at a time when very vascular granulation tissue was present, before the tissue had fully recovered from surgical traumatism and when cartilage, which has a low resistance, was exposed to the full force of the treatment.

Accumulation.—Experience has taught that it is not safe, in order to avoid cumulative effects, to repeat intensive treatments in less than three weeks. The interval will depend partly upon the size of the dose and its immediate effect on the skin. A three week interval may do for

a suberythema dose but from four to six weeks is required for erythema doses and a longer period if the reaction has been of the second degree. After the subsidence of a reaction the skin is likely to be hypersensitive for several weeks. The main reason for longer intervals is to avoid the possibility of delayed reactions. While it is true that if the skin is going to react it will do so in less than two weeks there are occasional instances where the reaction does not appear until the third, fourth and even the sixth week.

It has been shown by Kingery, a detailed description of whose work will be found on page 271, that the tissue loses 50 per cent. of irradiation effect in three and a half days. It is reduced to 5 per cent. on the fifteenth day and zero is reached about the end of the third week. No exception to this rule was encountered. This work does not include supersaturation with reaction where the tissues are injured beyond complete repair or where considerable time is required to overcome the damage.

With fractional doses accumulation to the point of supersaturation must be excluded before idiosyncrasy is blamed for an untoward result. This subject is considered in detail in Chapter XIX.

Filtration.—It seems to be the general belief that the skin is injured less by "hard" rays and filtered rays than by "soft" rays and unfiltered rays. Also that greater injury to the skin is caused by beta rays than by gamma rays. If we confine the discussion to the possibility of cutaneous injury the concensus of opinion, if not erroneous, is at least misleading. All rays—beta and gamma rays of radium, "hard" and "soft" *x*-rays, filtered or unfiltered rays—will severely and permanently injure the skin provided the amount is sufficiently large. In other words it is more a question of quantity than of quality (Chapter XIX).

Disease.—Certain diseases and conditions of the cutaneous envelope seem to make the skin more responsive to irradiation. Lesions associated with marked cutaneous congestion appear to be somewhat more sensitive to irradiation than does the surrounding skin—eczema, psoriasis, rosacea, mycosis fungoides, etc. This is especially true before acanthosis and hyperkeratosis or parakeratosis have developed. In diseases such as keloid and xanthoma the pathological skin does not appear to react more readily than does normal skin. Lesions associated with a markedly thickened horny layer tolerate very large doses such, for instance, as the common wart.

Before proceeding further it is advisable to agree upon a definition of the word idiosyncrasy as applied to *x*-rays and radium. In the light of our present knowledge it should be a natural or inherited tendency on the part of the skin to react vigorously to a minute dose of *x*-rays or radium. The skin of the entire body should show this tendency at all times. This excludes acquired susceptibility and variations in sensitiveness from causes and for reasons already enumerated; also variations due to errors in technic and judgment. It includes only those

variations for which, at the present time, there is no explanation. It is probable that examples of true idiosyncrasy of a mild degree are fairly common. But the degree is not sufficiently great to be beyond the margin of safety for practical work in expert hands. While it is probable that true idiosyncrasy of a severe type is occasionally encountered yet such examples must be extremely uncommon. In an experience of over fifteen years the writer has not met with a single case. Unexpected reactions have been encountered but when the normal skin on the corresponding part of the body of the same individual was exposed to the same dose no hypersensitiveness was noted. To prove the rarity of true idiosyncrasy one has but to review the history of the x-ray treatment of tinea tonsurans. In the roentgen laboratory of the Department of Dermatology and Syphilology, Medical Department, Columbia University, over a thousand cases of ringworm of the scalp have been irradiated without a single instance of idiosyncrasy being encountered. Hazen, of Washington, Pirie, of Montreal, Adamson, of England, and many others make the same report.

Prior to 1912 there were numerous reports of supposedly true idiosyncrasy, a few of which are herewith appended.

Bogrow and Grintschar (1912) believe that the most marked idiosyncratic tendency is when a given amount of radiation has twice the usual effect. Their opinion is based largely upon experiments made on a case of lupus. They call attention, also, to the fact that skin that has been irradiated is extremely susceptible to refrigeration (CO_2 snow). J. Hall-Edwards (1909) admits idiosyncrasy but finds that it is less frequently observed since improved methods of x-ray administration have been in vogue. The discussion following Hall-Edwards' communication shows considerable difference of opinion but a realization that the term idiosyncrasy, as applied to the roentgen ray, had been abused. Thedering (1912) did not recognize a true idiosyncrasy but he found a marked difference in susceptibility due to complexion, location, etc.

Sippel, in 1916, published an example of idiosyncrasy as follows: Two women, each seventy-five years of age, one a blond, the other a brunette. Cancer of the breast in both instances. The brunette received 24 exposures in fourteen months, the total dose being 600 X. The blond received 22 treatments over a period of eighteen months—total dose 462 X. The blond developed a severe reaction, the brunette did not. The technic of application, the apparatus and the operator were the same in both instances. The observation is open to criticism because a gas tube together with indirect estimation were employed. Complexion would not make such a marked difference.

Meyer, in 1915, noted a second degree radiodermatitis in four different areas in the same patient on two different occasions following the application of $\frac{3}{4}$ full dose. There had been no previous x-ray treatment. Assuming accurate technic the observation does not admit of argument.

Unusual Results.—There are a number of peculiar effects produced by *x*-rays and radium which are due apparently to individual peculiarities—idiosyncrasy. There is the precocious reaction—an erythema that develops in a day or two and disappears in from one to three weeks without developing beyond a first degree reaction. Then there are the radioerythema perstans and the delayed reaction. Some individuals freckle or tan as a result of very minute doses while others do not do so even when the skin is made to react. Following a reaction some dark skins may be depigmented. Telangiectasia develops much more readily in some skins than in others. The same is true relative to other sequelæ such as atrophy and keratoses.

After an epilating dose applied to the scalp the defluvium occurs ordinarily in the third week and the hair begins to grow again in the third month. It generally grows slowly, steadily and equally over the entire scalp and, as a rule, is of the same color, texture and general character as the original hair. The exceptions are as follows: The hair may fall out in two weeks or not until the fourth week. It may begin to regrow in six weeks or not until the sixth month. The growth may be exceedingly vigorous or equally sluggish. It may grow more rapidly in some areas than in others. The new hair may be curly while the original hair was straight, or *vice versa*. The new hair may be either lighter or darker than the original; it may be coarser or finer. Some of these phenomena may be explained by variations in dosage or by the effect of the disease, but individual peculiarities cannot be excluded in all of them.

In the heads of children there does not appear to be much variation in the dose required for depilation. In adults, however, it is not infrequent to encounter a fairly wide variation. We have seen depilation of scalp hair in an adult follow the application of H¾ S. D. It usually requires at least H1 S. D. for this purpose. In one instance (a case of favus) it required H2 S. D. (H8, 16 X) to cause the hair to fall. There was no erythema of the scalp which, incidently had been markedly altered by the disease. The skin of the back of this patient reacted normally to a dose of H1¼ S. D. The hair follicles may be hypersensitive when affected by disease. It has been noted that the diseased hairs in tinea tonsurans depilate more readily than do the normal hairs. Kienböck, and Meyer have noted this phenomenon, especially in psoriasis. The former obtained depilation of scalp hair in a case of psoriasis as a result of the administration of 2¼ X. His interpretation is hypersensitiveness of diseased follicles and not idiosyncrasy.

Radium.—Regarding spontaneous and acquired idiosyncrasy it is the author's experience and opinion that the same statements made relative to the *x*-rays answer also for radium. In the past, severe radium reactions were not as common as those associated with the administration of *x*-rays because radium was not in common use and because the technic was comparatively simple and, therefore, more

accurate. The radium reactions of recent years have been caused to a large extent by inexperience with the more complicated modern technic (emanation), by poor judgment, or by the various causes of and reasons for acquired hypersensitiveness as enumerated in this chapter.

SUMMARY.

1. Variations in cutaneous susceptibility to x-rays and radium and due to known causes are of daily occurrence. These variations may be well marked. They cannot be regarded as examples of true idiosyncrasy.
2. Slight variations in susceptibility of unknown and undiscoverable cause are not uncommon. These variations, at least until technic is more exact, may be considered as examples of true idiosyncrasy.
3. The existence of true idiosyncrasy of severe type is admitted but it is rarely encountered.
4. Individual peculiarities relative to pigmentation, defluvium, telangiectasia, atrophy, etc., are common and can probably be regarded as examples of idiosyncrasy.

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CHAPTER XVIII.

ACTION OF *X*-RAYS AND RADIUM ON PATHOLOGICAL TISSUE.

We have already discussed the cytological, biochemical and bacteriological action of radiation. It now remains to apply this knowledge, hypothetically and speculatively, in an attempt to explain the action of *x*-rays and radium in disease. The chief facts to be kept in mind are:

1. Minute amounts of radiation stimulate while large amounts inhibit and destroy.
2. Cells that are undifferentiated, immature, biologically or physiologically active, are most readily influenced.
3. Bacteria are not directly affected by gamma rays or *x*-rays. They may be killed by large amounts of beta rays.

STIMULATION.

Clinicians frequently speak of the stimulating action of radiation on disease and it is believed by many that some affections are cured or benefited by this attribute. The theory has been evolved partly because of the beneficial action of small amounts of radiation on affections such as eczema, psoriasis and particularly mycosis fungoides. These diseases, however, are associated with considerable cellular activity—acanthosis, infiltration—features that one might expect to see enhanced by stimulation, but which are probably inhibited by small doses on account of the susceptibility of biologically active cells. Furthermore, these affections and, in fact, most of the cutaneous diseases that yield readily to small amounts, are associated with considerable congestion or hyperemia. This means an increased local iron content which, when acted upon by gamma rays or *x*-rays, emits secondary radiations (beta rays) and these secondary beta rays may be largely responsible for the therapeutic results (Bragg, Keetman and Mayer, Abbe). The principal infiltrating cell in these affections is the lymphocyte and while its origin is under controversy, the consensus of opinion is that it constitutes a product of lymphoid evolution. Lymphoid tissue is so susceptible to radiation that even very small doses will exert an inhibitory action.

The stimulating effect of roentgenization has been blamed for the poor results in some cases of sarcoma and epithelioma. If an epithelioma is treated with fractional doses it is probable that there is an

initial stimulation which, however, is changed to inhibition in a few weeks because of accumulation. The degree of stimulation or inhibition will depend, naturally, upon the strength and frequency of the applications. It is possible that too much prominence has been given the stimulating effect of irradiation on malignant neoplasms. Wood and Prime, also many clinical observers, have noted an apparent stimulation subsequent to the administration of small amounts of *x*-rays and radium. By stimulation in this sense is meant increased cell proliferation by direct action of the radiation on the malignant cell. While such an effect is possible, even probable, there are other factors that must be considered in this connection. The increase in malignancy may be due partly to acquired resistance (page 282). Injury to surrounding structures, especially the lymphocytes (Murphy, Ellis, Morton, Millet and Mueller) may be an important factor. Superficial growths or the superficial portion of a fairly deep growth will at times undergo involution while the deeper malignant cells continue to proliferate. The rapidity of this deep proliferation may be enhanced, but there is more likely to be a temporary retardation with subsequent development which may be rapid or slow. It is unwise to attempt a definite opinion because the technic of cancer treatment is by no means fully developed, and because there is such a marked difference in the behavior of different types of sarcoma and epithelioma and, also, a difference in the behavior of the same type in different individuals, in varying anatomical situations, etc. The cause for continued or subsequent proliferation is probably incomplete inhibition and this is in many instances due to a dose that is sublethal, particularly in the deeper portions of the growth. It has been demonstrated by Lavine and Joseph, Wood and Prime and others, that mitosis can be temporarily prevented and a growth remain temporarily inactive without demonstrable microscopical alterations as a result of sublethal irradiation. The writer has seen both sarcoma and epithelioma apparently develop more rapidly as a result of *x*-ray treatment and in two instances epithelioma developed in patches of leukoplakia under intensive treatment with radium. While admitting that stimulation might be the cause of these phenomena it will be well, also, to consider the possibility of a pure coincidence, together with other factors already enumerated.

In this connection it has been claimed that irradiation of lupus erythematosus and lupus vulgaris favors the evolution of epithelioma. This may indeed be true if the dosage has been excessive. But there is no evidence that epithelioma in lupus tissue is more prevalent today than before the advent of *x*-rays and radium.

Hypertrichosis following *x*-ray treatment of acne vulgaris has been described, the growth of hair being due, it was thought, to the stimulating effect of the rays on the hair follicles. While this is possible, it must be admitted that hypertrichosis does not follow *x*-ray treatment of other diseases that require the same technic. Furthermore, super-

fluous hair is seen subsequent to acne vulgaris in instances where *x*-rays have not been employed. Acne vulgaris is associated with follicular and perifollicular hyperemia and it is treated with the same remedies employed in the various types of alopecia, all of which may stimulate the growth of hair in susceptible individuals and this susceptibility is seen very commonly in acne vulgaris. There is no corroborated evidence showing that the *x*-rays are capable of increasing the growth of hair. After depilation in tinea tonsurans it sometimes happens that the hair is greater in amount than before the treatment; the reverse is also true. It has been stated that fractional and even full doses of *x*-rays are beneficial in alopecia (Bordet, Holzknecht, Kienböck); the author has been unable to confirm these observations.

ANEMIA AND CONGESTION.

Tissue that is ischemic will tolerate considerably more radiation than will tissue possessed of normal circulation. Schwarz dehematized the skin by means of an elastic band and found that an area under the band would tolerate a much larger dose than would the skin outside of the band. Schmidt, by employing compression, was able to administer two erythema doses without reaction. After trying inconclusive experiments with adrenalin, the writer completely dehematized an entire forearm with an Esmarch bandage. While the forearm was bloodless a small area of skin was exposed to H1¼ S. D. (full erythema dose). The circulation was then restored and an adjacent area was exposed to the same quantity. The patient was seen two weeks after the experiment at which time there was an erythematous reaction in both areas, the reaction in the dehematized area being distinctly less intense than that of the normal area. Three weeks later the erythema in the dehematized area had disappeared while that of the normal area was still well marked.

It is of common occurrence, when administering large doses to small congested lesions, to have the surrounding normal skin react less vigorously than the congested lesion. This may be due, in part, to the fact that the periphery receives a little less radiation than does the center of the treated area. Again, even in congested lesions, if there happens to be considerable acanthosis and parakeratosis, the normal skin may react more vigorously than does the lesion. However, clinical and experimental evidence justifies the statement that congestion or hyperemia tends to increase "radiosensitiveness" while ischemia increases tissue toleration to some extent. The difference is supposed to be due to the secondary corpuscular rays (beta rays) from the iron contained in the red cells.

ACCUMULATION.

The effect of repeated irradiation is cumulative and accumulation results in inhibition. The degree of accumulation will depend upon the

size of the dose and the interval between treatments. Kingery has placed this question on scientific grounds. His work assumes a

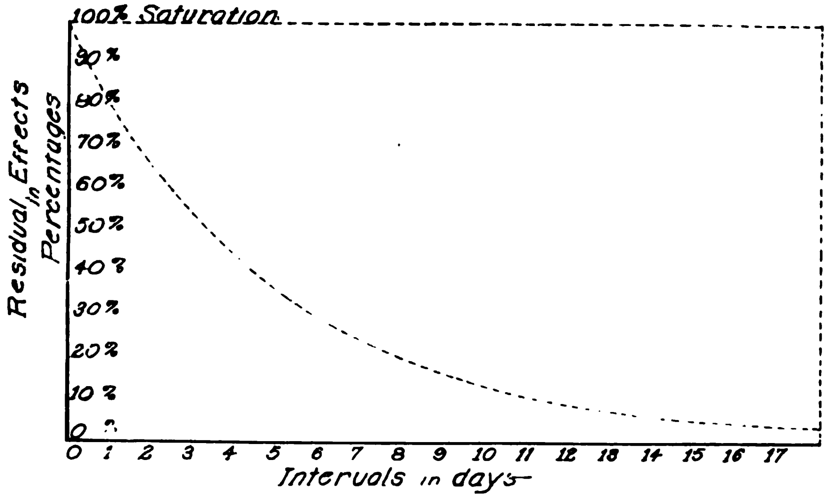

CHART 19.—Curve of residual effect, showing gradual decrease in tissue effects following one full dose of roentgen rays. (Kingery.)

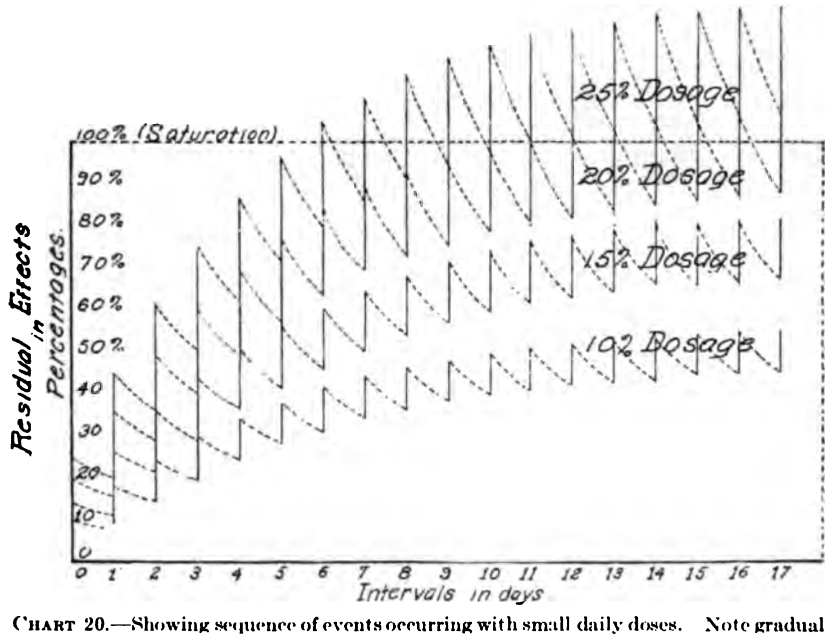

CHART 20.—Showing sequence of events occurring with small daily doses. Note gradual rise in value due to cumulative effect of small doses at daily intervals. (Kingery.)

hypothetical decomposition product in the tissues as a result of irradiation. By a large series of titration experiments he found that this

hypothetical substance obeys a well-known law of biology and chemistry—the law of mass reactions—the characteristics of which can be plotted. The rate of reduction of the irradiation effect (hypothetical substance) follows a definite law. The velocity of reduction varies directly with the degree of concentration. The greater the concentration the higher is the velocity of loss. As concentration decreases the velocity of loss becomes less in direct ratio. When concentration has

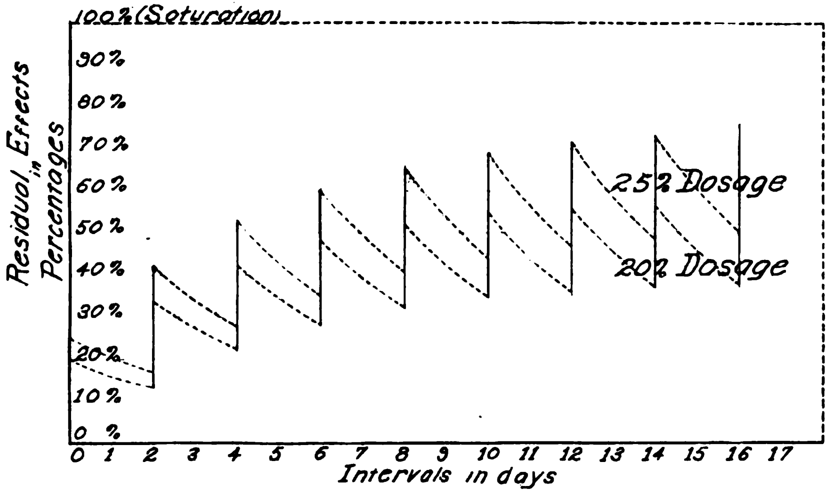

CHART 21.—Showing sequence of events occurring with small doses given on alternate days. Note gradual rise in value due to accumulation. (Kingery.)

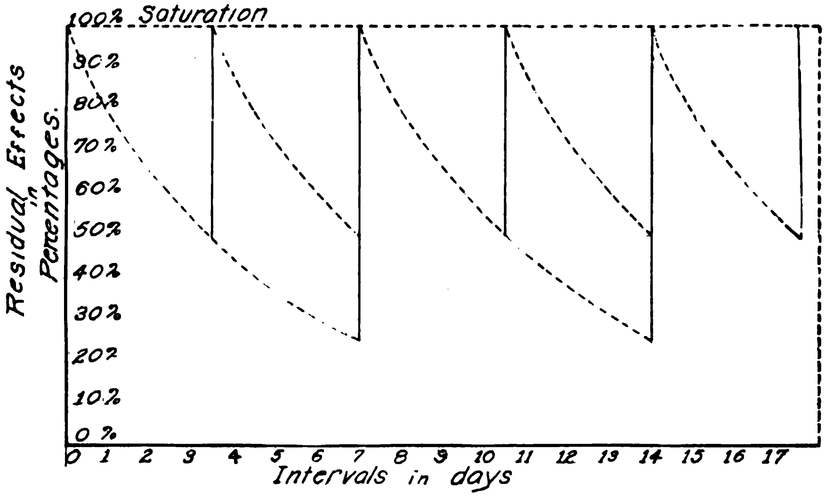

CHART 22.—Sequence of events following administration of 50 per cent. of full dose every three and a half days, and a 75 per cent. of full dose, every seven days, following initial full dose, of 100 per cent. (Kingery.)

been reduced to one-half, the velocity of loss has been reduced to one-half, etc. Chart 19 illustrates the law. It is seen that the half value point is reached in three and a half days, while the effect is not entirely lost for about three weeks. In order to maintain a saturation effect it would be necessary to administer one-half saturation dose every three and a half days or one-quarter saturation dose about every one and a half days.

Chart 20 shows the rate of accumulation with fractional doses administered daily. Chart 21 shows the rate of accumulation for the same doses every second day while Chart 22 shows the accumulation effect of a 50 per cent. dose administered every three and a half days and a 75 per cent. dose every seven days, following an initial 100 per cent. dose.

Kingery does not give his exact technic so that his saturation dose in terms of units is not known, but it may be assumed that he means an amount of radiation that is a little less than that required for a visible reaction on sensitive skin H¾ S. D. unfiltered or H1½ S. D. filtered. The report is so recent that there has been no time to test out the method in practical work. The writer has tried the method experimentally and in each instance there has been an erythematous reaction when, according to the chart, the accumulation was well below the saturation point.

Kingery's excellent work deserves very careful consideration. When the method has been carefully checked up biologically and has been adjusted to practical requirements it is likely to be of great service in the treatment of disease; especially in the treatment of cancer. Until then it is advisable to be cautious.

To return to the question of stimulation, the point to be emphasized is that the biological effect of fractional radiation, unless the treatments are several weeks apart, are cumulative and it is possible that the efficacy of a few small doses in diseases that are exceedingly amenable to such treatment, can be explained in part by the inhibitory action of accumulation.

BACTERIA.

In Chapter XIII it was shown that gamma rays and *x*-rays exert no appreciable influence on the growth of bacteria in culture. Beta rays possess a lethal effect on many bacteria to a depth of about [illegible] mm. The occasional quick response to roentgenization of such bacterial affections as sycosis vulgaris, acne vulgaris, and acne varioliformis has suggested the possibility of a direct or indirect effect on the causative micro-organisms. Theoretically the secondary beta rays evolved in the tissue may act directly on bacteria but the theory does not have experimental support. Positive cultures in bacterial and fungous affections, have been obtained repeatedly for days and even weeks subsequent to fractional and intensive radiation. An alternative explanation for the efficacy of *x*-rays and radium in certain bacterial

affections is that in some way the rays so modify the soil that the microörganisms find a less favorable medium upon which to grow. Whether this increased resistance is brought about by stimulation of enzymes or by some other biochemical process is not known. Several years ago Crane studied the opsonic index in 1 case of acne vulgaris, 2 cases of lupus vulgaris and 1 case of scrofuloderma during *x*-ray treatment. In all the patients the opsonic index was low before treatment was instituted. The treatments were of a strength sufficient to cause a slight temporary negative phase, followed by a positive phase which lasted several days. The treatments were given about once weekly. Each positive phase being a little higher than that of the preceding week, immunity was established in a few weeks and the eruptions disappeared. Crane's explanation was that the *x*-rays caused the production of an autogenous vaccine. The work has never been verified nor experimentally repudiated.

In this connection Hektoen found it possible by irradiating lymphoid tissue, to prevent the formation of antibodies soon after the administration of antigen. It is possible that very small doses might have had the opposite effect. Murphy, Ellis, Morton and others have been able to increase or decrease resistance against tuberculosis by roentgenizing lymphoid tissue. Tartarsky was able to reduce the lymphocytic count by subjecting a rabbit's ear to a prolonged exposure. It is conceivable that a short exposure or a series of properly spaced fractional doses might increase the lymphocytic count. As lymphoid tissue and the lymphocyte appear to be factors in the production of immunity they must be taken into consideration when discussing the possible indirect action of *x*-rays and radium on microörganisms in pathological tissue.

There is not much clinical evidence to support the sterilization theory in the *x*-ray or radium treatment of bacterial affections. But the favorable and prompt result occasionally seen in such definite staphylococcic affections as furunculosis (localized) and sycosis vulgaris indicates that irradiation is capable in some way and in some instances of increasing resistance against bacterial invasion. Most of the bacterial diseases that are readily amenable to irradiation are follicular in type and a possible explanation for its efficacy lies in the fact that the cutaneous appendages, particularly the hair follicles, are extremely susceptible to irradiation. Acne varioliformis (probably staphylococcic) and acne vulgaris (supposedly due to the acne bacillus and the staphylococcus) respond favorably and rapidly. Cutaneous tuberculosis yields very slowly and recurrences are common. The cutaneous lesions of syphilis and leprosy may improve under roentgenization but not to a useful degree. The common wart, a lesion of unknown infective origin (possibly bacterial), usually undergoes involution as a result of a single erythema dose. Conversely, the flat juvenile wart and other forms of verrucæ, possibly of bacterial etiology, are recalcitrant. Parasitic dermatitis is more stubborn than other

forms of eczema. It is well known that an incomplete depilation will often suffice to cure tinea tonsurans. This might be accepted as indicating a parasiticidal action, but a more reasonable interpretation is that the affected hairs depilate more readily than do the healthy hairs.

In concluding this phase of the subject suffice it to say that there is no experimental proof and very little clinical evidence in support of the sterilization theory as applied to microörganisms. It is possible that in some instances irradiation might increase resistance against the invading organism through some biochemical alteration. Perhaps a more probable hypothesis is that irradiation, by inhibition, destroys the reactive instead of the etiological factor, and the host, in the meantime, develops an increased local and perhaps general resistance.

INHIBITION.

In the light of present knowledge irradiation effects can be best explained, perhaps, by an inhibitory action on karyokinesis, on young cells, undifferentiated cells and cells that are physiologically very active. Most of the cutaneous affections that are amenable to irradiation, regardless of the cause, are associated with hyperemia and multiplication of tissue elements or overactivity of secreting epithelium. While the inhibitory theory appears to be satisfactory as an explanation for the effect of *x*-rays and radium on pathological tissue, it is quite possible that the action is complex and it may depend upon several different factors.

NEVI AND CONGENITAL AFFECTIONS.

In the hyperkeratotic group—ichthyosis, verrucous nevus, keratoderma palmaris et plantaris, etc.—there is a congenital anomaly which interferes with the process of normal keratinization. The result is a markedly thickened horny layer which exfoliates after irradiation. It is possible that the temporary relief is due to mitotic retardation in the basal-cell layer, although there may be, also, a direct influence on the process of keratinization. Stimulation certainly does not play an important rôle because the dose required for therapeutic effect is close to the amount for skin toleration. As soon as inhibition ceases the abnormal keratinization continues.

Vascular Nevi.—The elevated types of nevus vasculosis yield to radium in the most striking manner. Even the cavernous nevus will disappear under safe therapeutic dosage. It seems paradoxical but the superficial port-wine mark is exceedingly recalcitrant. The types that respond well begin after birth and continue to increase in size for weeks and months. There is a numerical increase in the blood-vessels which are dilated, abnormally cellular and which continue to develop by budding processes. In other words, a new growth in which

the cells are more or less embryonic in type. When irradiated it is probable that mitosis is arrested, new vessels cease to form and finally the poorly differentiated cells composing the vessels fail to be replaced and are absorbed. The troublesome port-wine mark is fully developed at birth, the cells are mature, well differentiated and not very active. It can, perhaps, be likened to telangiectasia. To cause an obliterating endarteritis in telangiectasia, spider nevus and port-wine mark requires an amount of treatment that may seriously injure normal tissue. The explanation of the effect of irradiation on lymphangioma is presumably the same as on angioma.

DISEASES DUE TO LOCAL CAUSES.

Of the many dermatoses falling under this heading, with the exception of eczema of external origin and the bacterial affections, two only are treated with *x*-rays and radium—corns and callus (cornu; callositas)—pathological hypertrophies. These lesions are characterized by acanthosis and particularly hyperkeratosis—a protective reaction to traumatism. Presumably the increased activity is in the lower part of the rete and in the basal-cell layer. Irradiation prevents further cell multiplication and the horny layer exfoliates. If in the meantime the local cause has been removed there will be no further development. It even seems possible to so modify the epidermis that it ceases to react to slight pressure or irritation.

It is difficult to comprehend the reason for the difference in the behavior of the various types of verrucæ when irradiated. The plantar wart, a reaction to pressure or friction, is very susceptible. So, also is verruca vulgaris, a hypertrophy supposedly due to microorganisms. Verruca plana, verruca filiformis, verruca acuminata, also possible bacterial hypertrophies, are less susceptible. Senile and seborrheic verrucæ, which are of unknown etiology, are less susceptible than verruca vulgaris. The difference may be a question of virulence and adaptability. In cases of multiple common warts irradiation of one wart or even of a lesion of another disease may be followed by a disappearance of all the warts (Delbanco, Halberstaedter and others). This has been thought to indicate the formation of antibodies or autogenous vaccines, but the same phenomenon has been observed in connection with other forms of treatment and then it must not be forgotten that warts occasionally disappear spontaneously and rather suddenly.

ECZEMA AND OTHER INFLAMMATIONS.

The effect of radiation on eczema, or dermatitis as it is now called by many, may be complex but it seems hardly necessary to invoke more than the usual inhibition hypothesis to explain the result. In the early stage of acute dermatitis when the objective symptoms

consist of erythema and edema, irradiation appears to exert very little effect. Even in vesicular dermatitis, if the vesiculation occurs before hyperplasia of the epidermis, treatment will not abort the eruption although further development may be prevented. After the leukocytic infiltration and especially acanthosis have been established irradiation is very effective, presumably by curbing mitosis and destroying very young cells. It might be argued that both the epidermal hyperplasia and the infiltration are protective and that inhibition of mitosis should be injurious instead of beneficial. In many inflammations, eczema included, the epidermal response is exaggerated and while at first it may be protective the later overgrowth is due to an excess of nutrition. It is the overgrowth that radium and *x*-rays tend to prevent. As for the infiltration, irradiation restricts the formation of new cells *in situ* but there is little if any effect on migratory cells from the blood stream. The local lesions of eczema are self-limited, they represent a reaction to an irritant and when the irritant is removed the lesions disappear spontaneously. Irradiation, while promoting resolution of individual lesions, does not seem to influence the etiological factor nor the disease. Unfortunately this is true of many of the dermatoses.

Accepting eczema as a pattern for the inflammations, the same explanations hold for affections such as psoriasis and lichen planus. Eczema and psoriasis occasionally become dermatitis exfoliativa, a condition likely to offer considerably more resistance than do its predecessors even in instances where the morphology is much the same. The reason for this resistance is possibly because of a more virulent virus or increased susceptibility to the virus, the resulting cutaneous reaction having a vitality that overbalances the inhibitory influence of therapeutic doses. Similar reasoning may hold for diseases which usually are favorably influenced but which occasionally fail to respond to irradiation. It not infrequently happens that a person's first few attacks of psoriasis will disappear promptly under the influence of the *x*-rays while later attacks may be irresponsive. The same phenomenon is observed in cases of mycosis fungoides, leukemia cutis, Hodgkin's disease, epithelioma, sarcoma, and rarely in other affections. Increased virulence of virus or increased susceptibility to virus may be factors here, but it is also advisable to consider the possibility of acquired resistance to irradiation, a subject that is discussed at the end of this chapter.

When treating generalized dermatoses, especially affections that are very "radiosensitive," such as mycosis fungoides, particularly if large surfaces are exposed to fairly large amounts of radiation, a febrile reaction is likely to develop together with a more or less generalized toxic rash, and the original eruption may become more manifest (Schuamann, White, Roman and others). These phenomena may be due to the rapid absorption of toxic material from the involuting lesions and, also, to a lowering of the lymphocyte count.

DISEASES DUE TO BACTERIA.

Sycosis vulgaris was mentioned under "Bacteria" at the beginning of this chapter. Many cases of pyogenic sycosis cannot be eradicated until permanent alopecia has been produced. It is easy to understand the mechanism of cure in such instances. It is more difficult to provide an explanation for cures obtained without even a temporary loss of hair.

Acne Vulgaris.—The pathology of acne vulgaris consists of a preliminary inflammation of the distal third of the hair follicle and of the sebaceous duct and gland. This inflammation is supposedly due to the acne bacillus and results in a hyperplasia and exfoliation of the follicular epithelium together with overactivity of the sebaceous glands. Exfoliation is largely responsible for the comedone; the pustule is due to the staphylococcus. Inhibiting cell division and sebaceous secretion with possible direct or indirect action on bacteria are the probable functions of irradiation in this disease.

Tuberculosis and other Granulomata.—Cutaneous tuberculosis belongs, pathologically, to the granulomata and as the discussion is of the granulomata rather than tuberculosis, we will include bacterial affections such as leprosy, syphilis, rhinoscleroma, fungus diseases such as blastomycosis and actinomycosis and, as representatives of the non-bacterial granulomata, mycosis fungoides, leukemia cutis, and granuloma annulare.[1] Mycosis fungoides and the entire lymphoid group of diseases respond quickly as a rule, although only temporarily, to irradiation—leukemia cutis, lymphogranulomatosis cutis, Hodgkin's disease, etc. The probable reason for this high degree of "radiosensitiveness" is the fact that the entire lymphatic system is easily and profoundly affected by both *x*-rays and radium. The lesions of granuloma annulare will usually undergo complete involution as a result of a single erythema dose. The non-bacterial granulomata are the most susceptible members of this group. The fungus diseases can be accorded second place as both actinomycosis and blastomycosis yield rather promptly as a rule to comparatively small doses.

The lesions of syphilis and leprosy will yield to a certain extent. The more benign types of cutaneous tuberculosis—sarcoid and erythema induratum—are quite susceptible. The inactive atrophic type of lupus vulgaris with deeply imbedded apple-jelly nodules, is particularly recalcitrant. The comparatively active hypertrophic lupus, ulcerated lupus and tuberculosis verrucosa cutis are more susceptible and the very active miliary lupus and tuberculosis orificialis are likely to be even more susceptible. With the exception of syphilis it will be noted that susceptibility bears some relation to duration and activity. The rapidly developing granulomata—actinomycosis, blastomycosis, granuloma annulare, miliary lupus—involute more rapidly under

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[1] Granuloma annulare may be a benign form of cutaneous tuberculosis or a tuberculide.

irradiation than do those of slow evolution—lupus vulgaris, rhinoscleroma. It is significant that the most inactive granuloma, barring leprosy, is the most resistant, namely, atrophic lupus vulgaris. Such observations tend to support the theory of inhibition. It is possible, too, that the type of infiltrating cell has something to do with radiosensitiveness—plasmomata seem to be less sensitive than the lymphomata.

DISEASES OF THE APPENDAGES.

All of the appendages, with the exception of the nails, and especially the hair follicles, are markedly influenced by irradiation. The comparative immunity of the nails may be due in part to filtration. The comparative susceptibility of the hair follicles is perhaps caused by the rapid cell division and the large number of young cells always present at or near the bulb. The action on the coil and sebaceous glands is presumably a retardation of physiological activity. Permanent results in hyperidrosis and seborrhea are due to atrophy of the coil and sebaceous glands. This may be due to a direct effect on the epithelium with hereditary transmission of acquired characteristics or to a lessened blood supply caused by sclerosis and contraction of the connective-tissue stroma. Many fungous and bacterial affections of the hair follicles cannot be cured by roentgenization without a defluvium. This is always so in tinea tonsurans and favus and very frequently in sycosis vulgaris, folliculitis decalvans, etc. In such instances irradiation acts as a depilatory, the microörganisms being removed with the hair.

PRURITUS.

It is stated repeatedly in the literature that the *x*-rays will relieve pain. This is true in instances where the pain was due to the presence of painful lesions that involuted as a result of irradiation. Occasionally applications of *x*-rays or of radium will relieve pain that is due to nerve inflammation—neuralgia. Occasionally, too, intensive treatments will be followed by neuralgic pain that lasts several weeks. Such observations support the belief that these radiations may exert a direct action on the nerves. That *x*-rays and radium will frequently allay severe itching is an accepted fact. When the pruritus is due to a cutaneous eruption its disappearance usually coincides with the involution of the eruption. It is difficult to explain why irradiation should overcome the symptoms of an affection such as pruritus ani. The effect is certainly not psychological. If it can be assumed that itching, in cases of pruritus without visible cutaneous changes and which is amenable to roentgenization, is due to alterations in the collagen or in the sensory terminals or fibrils (edema) it is conceivable that radiation acts by inhibiting chemical action and cell proliferation.

NEW GROWTHS.

There is an enormous difference in the susceptibility of the various new growths to irradiation. The basal-cell epithelioma is very susceptible as, also, is keloid. Squamous-cell epithelioma is much less susceptible. Cutaneous fibroma, myoma and neuroma hardly respond at all. The benign epithelial new growths—syringoma, tricho-epithelioma, multiple benign cystic epithelioma, etc.—are very recalcitrant. The same differences are noted in the sarcoma group. Benign endotheliomata (moles) are cured with difficulty. Giant-cell sarcoma is very susceptible, more so than either the spindle-cell or round-cell sarcoma. The difference in susceptibility seems to be partly one of cytology and morphology. The benign epitheliomata are quiescent lesions probably nevoid in character. The cells are mature, differentiated and are not undergoing rapid division. The basal-cell epithelioma is composed of cells that are constantly although not rapidly multiplying. The cells are derived from the stratum germinativum and show no tendency to produce keratohyaline. In other words they are immature and unspecialized, the type of cell that one might expect to see easily influenced by irradiation. Cutaneous prickle- or squamous-cell cancer is composed of cells that are undergoing rapid division but the cells are less embryonic in type and presumably for this reason more resistant. Soft fibromata (rapid proliferation of young connective-tissue cells) will yield to irradiation while hard fibromata, which consists of mature, differentiated fibrous tissue are highly resistant. It is probable that uterine myomata and fibromata are not directly affected by irradiation but indirectly through atrophy of the ovaries (Corscaden and others). The difference in susceptibility between keloid and hard fibroma may be due to the fact that the former is comparatively rapid in its evolution.

The Malignant Cell.—There has been a great deal of excellent experimental work with both *x*-rays and radium on the malignant cell. Colwell and Russ review the work up to 1915. The early experiments on animals with radium (Apolant, Wedd, Chambers and Russ and others) led to the belief that the favorable results were due largely if not entirely to beta rays but later, Dominici, Wood and Prime and others, demonstrated the lethal effect of gamma rays. In experiments on animals with *x*-rays many of the early workers used long wave lengths (soft rays) (Wedd and Russ and others), it being the opinion that long wave lengths were more effectual than were the short waves. Most investigators agree that beta rays are more efficacious than are gamma or *x*-rays but in therapeutic work it is not possible to employ them without danger of serious injury to the host excepting in superficial tumors. There is still a difference of opinion relative to the efficacy of short and long gamma rays and *x*-rays but thanks largely to the work of Wood and Prime it must be conceded that short wave lengths (filtered hard rays) are lethal when given in sufficient amount.

It is the consensus of opinion that the effect of radiation on the malignant cell is due to inhibition of cell division. As a general proposition the malignant cell is more "radiosensitive" than is the surrounding tissue. Unfortunately this is not always so. Radiologists have long recognized a marked variation of "radiosensitiveness" in malignant growths of different types. Some malignant cells are even less sensitive than rapidly growing connective tissue or the infiltrating lymphocytes. Wood and Prime, and Ewing have specifically remarked these features. The author has repeatedly noted a disappearance of the infiltrating lymphocytes without total destruction of malignant activity. One reason for the failure of the lethal doses completely to destroy all the cells in a favorably located, susceptible malignant growth, is the fact so well known to cytologists, that cells are relatively immune during their rest stage.

THE LETHAL DOSE.

Wedd and Russ, Wedd and Chambers, Pentimalli, Wassermann and others conducted interesting but inconclusive experiments with radium. Wood and Prime, in 1915, demonstrated the lethal dose for both beta and gamma rays *in vitro* and *in vivo* with certain experimental malignant tumors. Krönig and Friedrich found the *x*-ray lethal dose for both sarcoma and carcinoma to be a little less than the erythema dose. Seitz and Wintz increased the dose about 20 per cent. The most exhaustive work so far conducted was done by Wood and Prime in 1920. These investigators used short *x*-rays (9-inch gap) filtered through 3 mm. of aluminium. The tissue employed was mouse sarcoma 180, Crocker series, and mouse carcinoma 11, Crocker series. As a check on biologic effect, normal mouse embryo kidney was used. Sarcoma 180 is a rapidly growing large-cell sarcoma with but little interstitial tissue. It almost never undergoes spontaneous recession. Carcinoma 11 is a breast carcinoma of a medullary type, occasionally receding. The tissue was removed from mice, *x*-rayed, then one-half was used to inoculate mice while the other half was employed for *in vitro* growths in plasma. The results of this carefully conducted work are briefly summarized by Wood and Prime as follows:

"Approximately four erythema doses of roentgen rays given continuously and filtered through 3 mm. of aluminium are required to kill mouse carcinoma and five such doses to kill mouse sarcoma exposed *in vitro;* but occasionally some cells may escape the effects of even six doses.

"Approximately six erythema doses of roentgen rays are required to kill sarcoma cells *in vivo* as compared to five doses required to kill the same cells *in vitro;* and approximately six erythema doses are required to kill carcinoma cells *in vivo* as compared to four doses required to kill the same cells *in vitro.*

"The *in vitro* outgrowths from sarcoma tissue after four erythema doses of roentgen rays produced tumors when inoculated into mice.

"At least five erythema doses of roentgen rays are required to kill carcinoma and sarcoma cells in tissue cultures and at least four doses are required to kill embryonic connective tissue in cultures.

"The amount of *in vitro* growth is no indication whether the tumor cell is or is not capable of proliferating in the animal body. The growth observed after lethal doses is evidently due to the slow action of the rays which permits cells potentially dead to wander out into the medium and to complete a division process before their growth momentum is finally checked.

"Absence of mitotic figures after roentgen-ray treatment is not an indication of lack of ability of the cells to grow in the animal body.

"The practical conclusion which may be drawn from these observations is that the amount of roentgen rays necessary to kill all the cells of a rapidly growing, very cellular and highly malignant sarcoma or carcinoma in man is between five and seven erythema doses of filtered roentgen rays when the tumor is on the surface of the body. Every centimeter of tissue that covers the tumor makes an additional amount of roentgen rays necessary. For example, when slices of fibroid uterus are used as absorptive material, the galvanometer deflections show that at a depth of 2 cm., 19 per cent. more radiation is required; at 5 cm. depth, 47 per cent. more and at 10 cm. depth, 65 per cent. more. While many tumor cells may possibly be slowed in their progress and mitotic forms killed at such depths, it is doubtful whether all can be destroyed. The basal-cell tumors and the lymphosarcomata are, as is well known, much more susceptible to radiation. Small, superficial, metastatic carcinomata are also, in some instances, more susceptible than is the primary tumor."

ACQUIRED RESISTANCE.

Lesions of mycosis fungoides which are at first exceedingly susceptible to irradiation finally cease to respond even to large doses. This is true of the entire leukemic group of diseases. The same phenomenon is observed in epithelioma, especially when fractional instead of massive doses are administered. Occasionally, too, psoriasis and other affections will behave in the same manner. It seems that in certain diseases which have received long-continued treatment the cells develop a resistance that is apparently transmitted to future cell generations. Nogier and Regaud have noted this phenomenon in epithelioma but offer no explanation.

Conclusions.—Small doses of x-rays or radium rays at long intervals stimulate pathological tissue that is resistant to these agents. Very small doses so spaced that accumulation is avoided will stimulate susceptible tissue. It is possible, therefore, that in some diseases the stimulating effect of radiation may be beneficial and curative. Clinical and experimental evidence, however, point to the inhibitory influence

of radiation on pathological tissue as being the chief therapeutic factor. The indirect action on microörganisms, the effect on synthetic and autolytic enzymes and other biochemical actions, together with the effect on lymphoid tissue must also be taken into consideration. Present knowledge will not permit of too free generalization relative to the action of *x*-rays and radium on pathological tissue.

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CHAPTER XIX.

GENERAL THERAPEUTIC CONSIDERATIONS.

Dosage.—The object of therapeutic applications of *x*-rays and radium is to cure or relieve objective and subjective symptoms. If radiation is applied to a disease in which such treatment is contraindicated, thus making its symptoms worse, or because of excessive dosage an undesirable and even dangerous sequela is substituted for a harmless lesion, then the main object of roentgen therapy and radium therapy has been defeated.

Of the cutaneous affections that are amenable to irradiation the majority can be cured or improved by a quantity of radiation that will have no injurious effect on the skin. In such diseases as epithelioma and sarcoma, it is justifiable to produce a severe reaction when necessary. In the various types of cutaneous tuberculosis and other recalcitrant diseases, where large quantities are necessary for the purpose of cure, it may be impossible to avoid a first degree reaction. In severe types of hyperidrosis, sycosis vulgaris and acne vulgaris, it may be necessary to carry the treatment to the point of slight wrinkling of the skin. With the exception of the malignant neoplasms treatment should not be continued until a reaction ensues or a sequela develops unless absolutely necessary. If the operator is in doubt it is advisable to request a consultation and a division of responsibility. The main points to be emphasized here are that: first, prolonged treatment should be avoided. If a disease, usually amenable to a prescribed amount of irradiation over a given amount of time, fails to respond favorably to such treatment, it is advisable to discontinue the exposures. It is much better to lose a patient on account of failure to cure than it is to effect a cure at the expense of cosmetic disfigurement. The disease might be cured in some other way; the cosmetic defect from irradiation may be permanent. It is well to bear in mind constantly that repeated exposures over a long period of time, even without the advent of erythema, may lead to visible cutaneous atrophy and even to keratoses.

The second point is that excessive dosage is to be scrupulously avoided. Heavy dosage is indicated in epithelioma as already stated, but even here it is inadvisable to effect more than a first degree reaction or at the most a mild second degree reaction. In all other affections the author urges the avoidance of even a mild first degree reaction. This, of course, is not always possible. In some diseases—tinea tonsurans, sycosis vulgaris, lupus vulgaris—the margin of safety

between the lethal dose for the disease and the amount that might permanently injure the skin is small, in some instances too small to allow for the inaccuracy of the most modern technic. Allowance for human fallibility, not only in questions of technic but in matters of judgment, must be made.

In many cutaneous affections—keloid, acne vulgaris, circumscribed neurodermatitis, inveterate and nummular psoriasis, chronic squamous eczema, etc.—a single dose sufficient to effect an erythema, or a few fractional doses so spaced that an erythema is the immediate result, will suffice to effect a prompt cure. Severe examples of acne indurata will often undergo complete involution as a result of a mild first degree radiodermatitis. Such treatment, however, is not warranted. It cannot be too often stated nor too forcibly emphasized that a single erythematous reaction, even when exceedingly mild will in some persons be followed by wrinkling and telangiectasia. The slogan for radiologists, whether employing radium or *x*-rays, should be never to effect even a slight first degree reaction if it can possibly be avoided or unless the necessity for such reaction is a requisite for the cure of a dangerous or otherwise incurable disease. And in this connection a distinction must be made between a disease and a cosmetic condition such, for instance, as hypertrichosis.

Roentgen dosage is expressed in many ways. It seems desirable, until some better scheme is advocated, to create a standard dose for practical therapeutic work that possesses a fairly definite value as judged by the effect on the skin. This has already been done—the erythema dose. But there is no absolute nor generally accepted standard for the erythema dose. Hence we hear of the erythema dose, full dose, epilating dose, skin toleration dose, saturation dose, reaction dose, suberythema dose, intensive dose, massive dose, fractional dose, the skin unit, etc.

The following is offered for the purpose of standardizing dosage and to obtain a uniform nomenclature:

Erythema Dose.—The amount of *x*-rays necessary to effect definite erythema on a sensitive part of the body—face, anterior neck, axillæ, flexor surface of arms, and abdomen—(see chapter on Idiosyncrasy). Radiometrically the unfiltered erythema dose is 1 Holzknecht unit estimated *with pastille on the skin* (H1 S. D.; H4; 8 X; Chapter IX). The amount of unfiltered radiation required to produce a mild reaction in the skin will differ somewhat in different individuals. The so-called erythema dose (H1 S. D.) will not always provoke an erythema even on sensitive parts. Again there are persons whose skin may react slightly to three-quarters or even one-half this amount of radiation. The erythema dose as here established simply represents a standard unit of quantity that in the average person will produce more or less reaction on the skin.

In recording doses or in giving information relative to treatment, the operator should mention the essential details of the technic—

milliampèrage, spark gap or voltage, time, distance, filtered or unfiltered and if filtered the filtering material and its thickness. It is advisable also to mention the type of apparatus employed. Unless one operator is familiar with the technic employed by another operator it will not suffice to say simply that an erythema dose was administered. There would be too much possibility of error or misunderstanding. It is often necessary to refer a patient to another city for treatment. In such instances it is advisable to give details as follows:

April 25, 1920; erythema dose; H1 S. D.; Ma. 2; Sp.G. 6; T. 3 min.; D. 8 in.; interrupterless transformer; Coolidge tube; unfiltered. Also information relative to number of treatments, time between treatments, effect of previous treatments, suggestions as to further treatment, etc.

The standard erythema dose for *x*-rays filtered through 3 mm. of aluminium is H2 S. D.

Accepting the erythema dose or "skin unit" as above standardized it becomes possible to give a reasonably definite meaning to certain terms so often employed in this country.

Intensive or Massive Dose.—The amount of radiation required to provoke a mild erythematous reaction in sensitive normal skin. In other words, an erythema dose.

Hyperintensive Dose.—A quantity sufficient to provoke a pronounced erythema or a mild second degree reaction in normal skin.

Ultra-intensive Dose.—An application that will cause a severe second degree reaction or a third degree reaction in normal skin.

Subintensive Dose.—Three-quarters of the erythema dose. Also spoken of as the suberythema dose, skin toleration dose and saturation dose.

Semi-intensive Dose.—One-half of the erythema dose.

Fractional Dose.—One-quarter of the erythema dose.

Subfractional Dose.—One-sixteenth or one-eighth of the erythema dose.

These terms can be used only when dealing in generalities. They may be employed in both roentgen therapy and radium therapy. When signifying *x*-ray exposures they may be expressed in figures (the doses are estimated at full distance, *i. e.*, with pastille on the skin):

Intensive – H1 unfiltered. H2 filtered with 3 mm. of aluminium.
Hyperintensive—H1 to H2 unfiltered. H2 to H4 filtered.
Ultra-intensive—H2 to H3 unfiltered. H3 to H6 filtered.
Subintensive – $H\frac{3}{4}$ unfiltered. $H1\frac{1}{2}$ filtered.
Semi-intensive—$H\frac{1}{2}$ unfiltered. H1 filtered.
Fractional—$H\frac{1}{4}$ unfiltered. $H\frac{1}{2}$ filtered.
Subfractional—$H\frac{1}{16}$ to $H\frac{1}{8}$ unfiltered. $H\frac{1}{4}$ filtered.

It is not practical to use radiometric numerals in recording radium applications. Here it is necessary to mention the type, size and strength of the applicator, exposure time, distance from the surface and thickness of the filter as well as the material of which it is composed (Chapter XII).

Rest Intervals Between Treatments.—It is desirable that there should be an agreement relative to the length of the rest periods allowed between treatments. This is advisable in order to avoid injurious results and also to clearly differentiate between fractional and intensive treatment. Obviously, if fractional or semi-intensive applications are administered every day or two accumulation will very soon result in an intensive effect. It would be misleading to apply the term fractional to such treatment. Practically all radiologists are agreed that a rest of at least three weeks should be allowed between intensive treatments. There is no agreement relative to fractional treatment. In attempting to standardize the rest period one must have in mind several possibilities. Treatments should not be so far apart as to jeopardize therapeutic efficacy. But the rest interval must be of a length that will insure against injurious accumulation. Delayed reactions, prolonged reactions, sensitized skin, etc., also should enter into the calculations.

As a routine the following procedure has given satisfaction.

Intensive Treatments.—Intensive doses may be repeated at intervals of four weeks providing there has been no reaction. If there has been a reaction the next treatment is not given for at least two weeks after the reaction has subsided. Intensive treatment includes the administration of fractional treatments so spaced in time that an intense effect is obtained within two weeks.

Hyperintensive Treatment.—These treatments will provoke a reaction in all but lesions possessing a very thick horny layer such, for instance, as plantar warts, cornu, etc. If there is no reaction the treatment may be repeated in from four to six weeks. But, in case of reaction, a rest of one month should be allowed after complete disappearance of the reaction.

Ultra-intensive Treatment.—Here, too, the rest interval will depend upon the degree of reaction and, also, the type of lesion. Treatments should not be repeated in less than six weeks in any case. At least a month should elapse after the subsidence of a reaction before the treatment is repeated.

Subintensive Treatment.—As a routine the treatments are given every four weeks.

Semi-intensive Treatment.—As a routine, every two or three weeks.

Fractional Treatment.—Once weekly.

Subfractional Treatment.—Twice weekly.

Fractional Versus Intensive Treatment.—Originally, all *x*-ray and radium treatment was of the fractional type. When radiometric measurement (the first accurate method of estimating roentgen dosage) was first instituted it was found most reliable with large doses. As soon as large, carefully measured applications were widely employed superior therapeutic results were noted. These superior results were thought to be caused partly by greater accuracy in dosage and partly by the biological effect of massive applications. To appreciate this evolution of ideas (the word revolution might well be used) it should

to a group of very small lesions between which there is normal skin. The normal skin in such instances can be protected by cutting holes, of the correct number, size and shape, in a piece of lead foil. Another method is to coat the skin with a 50 per cent. bismuth or zinc oxide paste. When employing these heavy elements (lead, zinc, bismuth, etc.) for this purpose, the possible effect of "soft" secondary radiation must be considered. However, with the doses used in cutaneous roentgen therapy, no harm has resulted when employing these materials.

Many operators judge of the spread of the rays by observing the illumination of the skin caused by the light from the Coolidge filament. This, however, is not accurate as the filament and the focal spot on the anode are quite a distance apart. A better plan is to place a fluorescent screen over the region to be irradiated. When the tube is in operation the part of the screen acted upon by the radiation will fluoresce brilliantly, thus outlining the area of radiation. Such a screen, suitably ruled, may be used to center the target over the center of the lesion. It is a good idea to have the screen backed with heavy lead-glass so that no radiation will reach the lesion before the actual treatment is begun.

Direct and Oblique Rays.—There is a physical law that has received considerable attention by radiologists: Intensity varies: (1) inversely as the square of the distance and (2) directly as the sine of the angle of incidence. For the sake of simplicity the second way of expressing this law may be disregarded as the first will cover all questions relating to the second. The so-called direct rays are those that pass from the target straight to the lesion. The so-called oblique rays strike the skin around the lesion and are less intense for the simple reason that they have to travel a greater distance. Fig. 90 shows the difference in the length of the direct and the oblique rays falling upon a flat surface and derived from minute points at distances of 6, 8, 10 and 12 inches. At first glance it would seem as though there might be an enormous difference in intensity at the periphery when comparing the 6 and 12-inch skin-focal distances. As a matter of fact the difference is not great. With an 8-inch skin-focal distance the loss of intensity at 6 inches from the center of a flat surface is $\frac{1}{3}$. With a skin-focal distance of 12 inches the loss is between $\frac{1}{3}$ and $\frac{1}{4}$. At a distance of 32 inches the loss is about $\frac{1}{16}$. At very short distances the difference is greater.

Treatment of Large Lesions on Flat Surfaces.—It is customary to place the anode over the center of a large lesion and allow the rays to spread over the entire affected area. As shown in the preceding paragraph a lesion a foot square will receive $\frac{1}{3}$ less intensity at the periphery than at the center, with the usual working distance of 8 inches. Individual lesions seldom have a diameter of more than 6 inches so that this loss of intensity is of no practical importance for flat surfaces or for lesions that are easily cured. In epithelioma, however, it is essential that intensity be fairly uniform over the entire surface. In this connection

it might be well to state that oblique rays passing through a tumor of considerable thickness will be compelled to penetrate more tissue than will the direct rays so that in addition to loss of intensity by distance there is also a loss caused by additional absorption.

There are two ways in which intensity can be fairly equally distributed over a large flat surface. First, by increasing the skin-focal distance to at least 32 inches, preferably 4 or 5 feet. An increase in the length of the skin-focal distance as shown by Kienböck, Holzknecht, Schultz and others, causes greater intensity at a given depth below the surface (Chapter II). A long skin-focal distance is advantageous, therefore, in the treatment of large lesions and thick lesions. The second method consists of dividing the lesion into two or more areas; each area is then given a separate treatment. It is necessary to fit the protecting material very accurately so as to avoid overlapping of exposures or to leave parts of a lesion unexposed. It is customary to

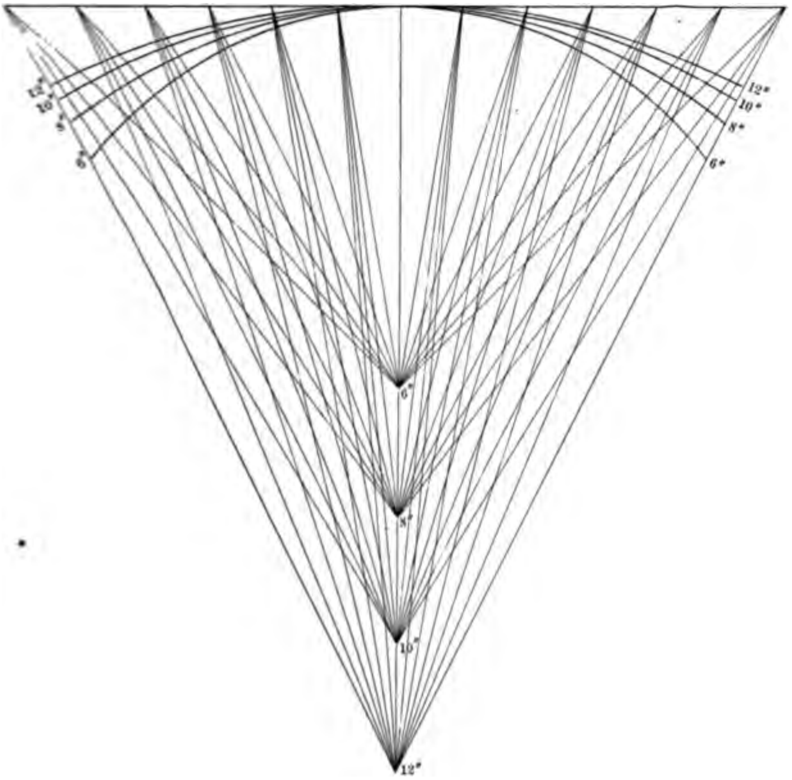

FIG. 90.—Showing the spread of radiation with skin-target distance of 6, 8, 10 and 12 inches. Shows the loss of intensity as the sine of angle of incidence or inversely as the square of the distance. Shows also the degree of concavity necessary to equalize intensity over an extensive surface.

mark out the areas with a skin pencil and allow about a quarter of an inch between areas. It is presumed that this amount of tissue will be take care of by the scattered and secondary rays. The lead foil, or other protecting material, should be firmly fastened to the skin by adhesive plaster or weights. This is the popular method in both *x*-ray and radium treatment. (For treatment of large lesions on flat surfaces with radium see Chapter XII.)

Treatment of Convex and Concave Surfaces.—Irradiation of convex and concave lesions of fairly large dimensions is associated with considerable difficulty. The method of applying radium, in the shape of flexible applicators, radium packs, etc., is described in Chapter XII. In *x*-ray work a slight concavity may be just sufficient to overcome the loss of intensity at the periphery. Or, the surface may be so concave that the periphery of the lesion or certain normal parts may be actually closer to the anode than is the center of the lesion. It is these depressed and crateriform areas that stimulate the resourcefulness of the technician. As examples of such surfaces may be mentioned the inner canthus and the anal region. These surfaces can be flattened out to some extent by pressure or by spreading the tissues apart. If this cannot be accomplished, a reasonable equalization of intensity can be obtained by shielding all but the floor of the concavity and applying from $\frac{1}{4}$ to $\frac{1}{2}$ the desired dose, the amount depending upon the slope of the walls of the concave surface. The shield is then removed and the exposure continued until the full dose has been administered. The curved lines in Fig. 90 indicate the degree of concavity required to equalize intensity over a surface of any size.

Convex surfaces are troublesome because, with the anode centered over the center of a lesion, the distance from the source of irradiation to the periphery of the lesion may be considerably increased as compared with a flat surface of the same size. Indeed, the surface may be so convex that the periphery of the lesion may receive no radiation at all. In such instances it may be necessary to make multiple exposures. Take, for instance, a lesion occupying the anterior and lateral surfaces of the forearm. Three exposures are required—one for the anterior and one for each lateral surface. If each exposure is at right angles to the other no protection is required—the rays from each are allowed to overlap.

Generalized Roentgenization.—Not infrequently it is necessary to apply the *x*-rays to practically the entire body. The requisites are first, not to lower the lymphocytic count; second, not to cause too rapid involution of lesions; third, reasonably uniform distribution of intensity. Not only must the dose be small but only a small section of the body should be exposed on any one day. It is customary to divide the body into from four to six areas and to apply a fractional dose to one area each day. No section of the body is treated more than once a week. The body surface may be divided somewhat as follows:

First.—Head and Face.—This requires five exposures, the angles of incidence being the same as those used in the treatment of tinea tonsurans (Chapter XXI). The face and neck are not shielded. In fact, in generalized roentgenization, no shield other than the regular tube shield is used. And, incidentally, the diaphragm of the tube shield must be large, or the tube will have to be placed at a considerable distance from the skin. It is to be understood that the eyes, eyebrows, ovaries and testes are suitably protected or that the dose is to be too small to injure these parts. These details are discussed in other chapters.

Second.—Chest, Abdomen and Anterior Surfaces of the Arms, Forearms and Hands.—Four Exposures.—The arms are held in contact with the trunk, on a level with the abdomen. If the arms are long the hands will not be included in this section and will receive treatment when the thighs are exposed. Exposures are made over each side of the chest with the anode centered between the nipples and the anterior axillary folds. Similar exposures are made over the abdomen with the tube 8 or 9 inches to one side of the umbilicus.

Third.—Entire back, including the posterior surfaces of the arms and forearms. Four exposures are required as in the last section.

Four.—Anterior Surfaces of the Thighs and Legs.—Six exposures are usually required—two for the anterior and posterior surfaces of the thighs, two for the anterior and posterior surfaces of the knees and two for the anterior and posterior surfaces of the legs.

Many persons will not be able to tolerate this amount of treatment and, furthermore, it may be necessary to treat the lateral surfaces of the arms, thighs, legs and trunk separately. In universal eruptions it is, therefore, preferable to divide the cutaneous surface into six sections, begin with subfractional treatments, make frequent blood counts and watch for constitutional symptoms.

Systemic Reactions.—Various types of systemic reactions are encountered subsequent to general roentgenization, or following fairly intensive irradiation of small areas. Schaumann observed a generalized, itchy, papular eruption following intensive roentgenization of the spleen in a case of splenic leukemia. Engle reports a sharp febrile reaction, toxic symptoms and death subsequent to rather intensive irradiation in a case of splenomyelogenous leukemia. Fricke had a similar case in which there was a generalized cutaneous eruption of psoriatic type. Sterne, Edwards, Pancoast, Allen, and Pusey, call attention to systemic reactions of a toxic nature and cutaneous eruptions associated with the roentgen treatment of cancer and leukemia. White and Burns, Roman, Allen, Dock, Haret, Lyle, Franklin, and Linser, have reported symptoms of toxemia, including cutaneous eruptions during the treatment of generalized and localized mycosis fungoides. Gibson, Nielson, Kienböck, and Holzknecht, have seen scarlatiniform eruptions with and without febrile reaction, follow roentgenization of various diseases. Holzknecht has noted scarlatini-

form eruptions associated with a local radiodermatitis. The author has seen cutaneous and constitutional reactions of a toxic nature follow the too vigorous irradiation of mycosis fungoides, leukemia, cancer and psoriasis.

Reactions as above outlined were observed more frequently in former years than in recent years. They were noted at a time in the evolution of roentgen therapy when technic was uncertain and when the biological action of *x*-rays and radium was not well understood.

The cause of such reactions is probably a destruction of cellular elements with the absorption of foreign proteins or biochemical products to which the organism reacts. This is seen in the too intensive irradiation of pathological tissue that is readily amenable to such treatment—mycosis fungoides, leukemia, psoriasis, certain types of cancer, etc. It is possible, also, that too vigorous generalized irradiation may cause a systemic reaction by the destruction of lymphoid tissue.

There is another type of systemic reaction which is very commonly encountered subsequent to the administration of heavy, filtered doses of either roentgen rays or radium rays. The reaction occurs within a few hours after the treatment and may last from a day to a week. It consists of varying degrees of anorexia, nausea, vomiting, headache, chills, fever and prostration. Pfahler, Béclére, Jones and Roth, Lang and others have studied such reactions carefully but the etiology has not been definitely determined nor is there any certain way to avoid them. Pfahler believes that the reaction is due to gases (ozone, etc.) produced by the effect of the high-tension electricity on the air or in the case of radium, by ionization, and inhaled by the patient. Lang is of the opinion that the effect is due to acidosis. Jones and Roth call attention to the fact that the reaction in question occurs subsequent only to irradiation of the abdomen and lower chest; that it is not observed when the vagus nerve does not fall in the field of treatment. These authors have observed different types of reactions when various parts of the body have been irradiated and conclude that the reaction is due to the direct effect of the radiation on human tissue. When the region of the salivary glands was irradiated they found alterations in the salivary secretion, taste and smell. When the gastric glands and vagus nerve were irradiated nausea and vomiting was the result. Ewing has made similar observations. Béclére calls attention to the fact that nausea and vomiting may follow large amounts of radiation applied to the cervical and axillary regions, to any part of the abdomen (even as a result of radium in the vagina) and to the chest. Such observations are in accord with the experience of most radiologists. Béclére's conclusion is that the reaction in question is caused chiefly by the adulteration of the blood with toxic substances resulting from the disintegration of the pathological or normal cellular elements destroyed by the radiation. Also that there might be a direct action on the nerves.

Local Medication.—Intensive treatment should not be administered to persons who have been applying stimulating or irritating applications to the affected part. Fractional treatment is permissible but caution is advisable (see Chapters XV and XVII).

Cross-fire Treatment.—It is often difficult, even with filtration and increase of skin-focal distance, to apply a sufficient amount of radiation to the deeper parts of a thick lesion or to a subcutaneous tumor without serious injury to the overlying tissues. Cross-firing is the utilization of two or more ports of entry. Through each port is passed a skin toleration dose. The result is that a subcutaneous tumor receives the radiation, minus decrease of intensity by absorption and distance, from each port, but no one portion of the skin receives more than one exposure. Assume an epithelioma involving the skin and deep tissues of the nose. Cross-fire treatment would consist of an *x*-ray treatment externally and a radium tube placed inside of the nose. A subcutaneous tumor of the thumb might be cross-fired from four angles—anterior, lateral and posterior surfaces. Large cutaneous tumors that are considerably elevated may be cross-fired by dividing the mass into several squares. Also radium needles can be inserted into various parts of the growth (see Chapters XI and XII).

Estimation of Intensity Below the Surface.—There is as yet no accurate means of estimating intensity in the deeper tissues. If the energy is derived from a small area such as the focal point of a Coolidge tube, intensity will vary inversely as the square of the distance. This law is not strictly applicable, however, where the source of supply represents a surface of relatively large dimensions—flat radium applicator—or where the energy is derived from a source that has depth—radium tube containing a considerable quantity of radium salts. In addition to loss of intensity by distance there is the loss by absorption. Absorption of radiation by human tissues varies with the density and the density will vary with the physiological and pathological conditions. Also loss of intensity by absorption varies according to the type of radiation. Roughly speaking heavily screened radium will lose about 3 per cent. of its energy in passing through 1 cm. of soft tissue (Viol); the loss in the case of *x*-rays has been variously estimated at from 6 to 10 per cent. Inasmuch as loss of intensity by absorption of homogeneous radiation tends to follow an exponential law, the loss will be progressively less with each additional centimeter of tissue of like density. When attempting to estimate intensity at a given depth it must not be forgotten that oblique rays travel a greater distance and through more tissue than does the direct beam. Finally, when the source of radiation is at a distance the oblique rays are more perpendicular, therefore there is a greater concentration of radiation at a given depth below the surface. (For further details relative to estimation of dosage below the surface see Chapters XI and XII.)

Filtration.—The object of filtration, the technic of which is described in Chapter XI, is to remove the rays that are absorbed by the super-

ficial tissues. By suitable filtration the x-ray beam is made more homogeneous and as, with such radiation, there is less absorption by superficial tissue, there is a more uniform intensity throughout the deeper tissues. Filtration is therefore indicated in the treatment of subcutaneous tumors and nodules such as erythema induratum, sarcoid, certain types of epithelioma and sarcoma, tuberculous adenitis, etc. Also diseases in which the pathological tissue is of considerable volume—keloid, epithelioma, etc.

It has been said that filtered x-rays are advantageous in all but the most superficial dermatoses (Gunsett, Regaud and Nogier, and others). Many roentgenologists aver that filtration when employed in diseases of the appendages—acne vulgaris, sycosis, hypertrichosis, hyperidrosis, etc.—will effect the desired result with less injury to the normal skin than is the case with unfiltered rays. The theory is that the appendages being situated fairly deep in the true skin, should be exposed to radiation from which has been removed the wave lengths that will be entirely or mostly absorbed by the epidermis and superficial part of the derma. With spark-gap lengths ordinarily used in practice (6 to 9 inches) it is doubtful if there are many wave lengths that are completely stopped by the epidermis and papillary body. Even in cases of radiodermatitis due to very long wave lengths (2- or 3-inch spark gap) the microscope shows the true skin injured to its full depth, the active ulceration of the more superficial tissue being largely if not entirely due to vascular changes and not to the direct action of the radiation on the cellular elements of the epidermis. Certainly the x-rays from a roentgen bulb never effect the exceedingly superficial reactions that are caused by the secondary radiations from lead or those produced by the beta rays of radium. The nearest approach to such superficial reactions is seen when an x-ray tube is placed in contact with or within a few centimeters of the skin.

As indicated in Chapters II, XI and XII distance is an important factor when it is desired to obtain a more even distribution of intensity throughout several centimeters of tissue. Of course the same theory holds true for a few millimeters of tissue as well as a few centimeters of tissue. With the glass wall of the tube within a few millimeters of the skin there will be more absorption of radiation by the first few layers of tissue than when the tube is placed at the usual working distance of from 6 to 12 inches. The most superficial effects that can be produced by roentgen rays are obtained by using a short gap (2 or 3 inches) and placing the wall of the tube within an inch of the skin.

It cannot be denied that with filtered radiation there is a more equal distribution of intensity throughout the few millimeters of tissue comprising the normal derma and that, theoretically at least, such radiation is indicated when it is desired to influence the appendages that lie in the middle or lower part of the true skin.

In practical work it is possible that a filter is preferable in all but the most superficial affections, but no one has yet proved this to be the

case. Let us apply the theory to some definite affection—hypertrichosis. In this condition it is necessary to effect a permanent loss of hair. To do this requires permanent atrophy of the hair follicles. Naturally one prefers to accomplish the desired result without visible injury to the skin as a whole. At first thought it would seem advisable to use filtered "hard" rays with the tube at a distance so as to avoid a relatively high absorption of radiation by the epidermis and upper derma. But this does not seem to give much if any better results in practice than do unfiltered rays with ordinary spark gap lengths (6 to 9 inches). The explanation is probably that with such thin tissue the difference in absorption for the first few layers is not very great for unfiltered and filtered radiation when the roentgen tube is at a distance of at least 6 inches and the spark gap length is at least 6 inches. More important, perhaps, is the fact that no matter what quality of radiation is used, the follicles must be destroyed. And, in spite of the fact that the hair follicles are more susceptible than is the surrounding connective tissue to the effect of radiation, when a sufficient amount of any quality of radiation has been absorbed by the follicles to effect their permanent destruction, the other structures are likely to show degenerative changes that will lead to visible wrinkling. In this connection it should be remembered that the epilating-dose for unfiltered roentgen rays, as estimated radiometrically, is H1 S. D. Estimated in the same manner the epilating dose for filtered radiation is H2 S. D. Both will produce an erythema on sensitive skin. It must be admitted, though, that there is a little more latitude between the minimum and maximum epilating and skin toleration doses in the case of filtered rays than in the case of unfiltered rays.

In the author's experience it has been difficult to ascertain the real value of filtration in diseases that affect only a few millimeters of tissue because the results have appeared to be the same with both filtered and unfiltered radiation. It is, of course, quite a different proposition when we are dealing with pathological tissue of considerable depth or with subcutaneous affections.

Experiments with filtered and unfiltered *x*-rays, in symmetrical superficial eruptions or in lesions of a size that permits of one-half being exposed to filtered and the other half to unfiltered rays, seem to show that there is little if any difference in efficacy providing the quantity of the filtered rays (3 mm. Al.) is always double (by pastille estimation) that of the unfiltered rays. This may not be true for all superficial diseases but very little difference was noted in such affections as mycosis fungoides, acne, psoriasis and eczema. If this work can be corroborated by others it will tend to indicate that quality is much less important than quantity in superficial therapeutic work.

Apparatus such as the "oil-immersed generating outfit" described in Chapter III, promises to replace the interrupterless transformer for some kinds of roentgenological work. Unfiltered radiation is not obtainable with this apparatus. As a stimulus to the evolution and

use of such apparatus it is the writer's opinion that filtered *x*-rays are as efficacious in cutaneous diseases as are unfiltered *x*-rays.

What has been said of the *x*-rays, relative to filtration, can be applied to radium but only in respect to the gamma rays. The beta rays are entirely stopped by a few centimeters of human tissue. Furthermore, they are extremely active ionizers and exert a profound influence upon superficial tissues. When applying radium for deep effects it is essential that the beta rays be entirely eliminated. This can be accomplished by filtering or screening with 4 or 5 mm. of aluminium or from $\frac{1}{10}$ to $\frac{1}{2}$ mm. of lead. Such filtration will also prevent the passage of "soft" gamma rays. Two or three millimeters of lead or from 1 to $1\frac{1}{2}$ mm. of platinum, will cut out all but the most penetrating gamma rays, thus making the radiation practically homogeneous.

Unfiltered beta rays are reduced to about 6 per cent. of their original intensity after passing through 1 cm. of human tissue (Colwell and Russ). One-half to 1 mm. of aluminium will eliminate the "soft" and "medium" beta rays and the very "soft" gamma rays. By such screening and sufficient exposure it is possible to obtain a pronounced direct beta ray effect to a depth of from 2 to 4 cm. Normal skin ranges in thickness from 1 mm. to perhaps 5 mm. In disease this thickness varies from $\frac{1}{4}$ to 4 cm. It is obvious, therefore, that the thickness of tissue is of considerable importance where beta rays are employed. It would seem advisable when employing radium, to always use at least a very thin screen—from $\frac{1}{25}$ to $\frac{1}{10}$ mm. aluminium—even for the treatment of superficial conditions.

Treatment of Thick Lesions and Deep-Seated Lesions.—For detailed information relative to the treatment of thick and deep-seated lesions the reader is referred to the preceding paragraphs of this chapter—also to the chapters on General Physics, Radium Technic and Filtered *X*-ray Technic. It is obvious that there are several ways in which intensity can be increased in the deeper tissues without subjecting the superficial tissues to increased radiation—filtration, cross-fire, increase of distance and dehematization. The last is described in Chapter XVIII.

Distance.—The operator should take note of the important fact that errors in dosage resulting from errors made in measuring distance are far more serious for small distances than for great distances. For example, if the dose at 6 inches is taken as a unit and the operator makes an error of 1 inch in the distance, making it 5 inches instead of 6 inches, then the dose received at 5 inches is actually $\frac{36}{25}$ of that at 6 inches or, since intensity at 6 inches is taken as a unit, it is 1.44 units. That is, the dose is increased by 44 per cent. due to the error of one inch. Now suppose a certain dose at 12 inches is taken as a unit and the operator makes the distance 11 inches instead of 12 inches, the actual dose will also be increased but in the ratio of $\frac{44}{121}$ or 1.19 as compared to that at 6 inches. That is, the dose will be 19 per cent. too great. It is thus seen that the same error in distance—one inch in each case—makes

an error in dosage of 44 per cent. at 6 inches and only 19 per cent. at 12 inches.

Quality and Quantity.—It has been the opinion of most roentgenologists and it is still the opinion of many that there is a pronounced difference in the biological and therapeutical value of *x*-rays of varying degrees of penetrability ("hardness"). It certainly appears to be the consensus of opinion that "soft" rays are especially indicated in the treatment of superficial diseases. Schultz even endeavors to select a quality that will be absorbed most readily by tissue of a certain specific gravity—hence his advocacy of "very soft" and "over soft" radiation. The author has not been able to confirm these findings and opinions. The effect, as evidenced by cutaneous reactions, is always the same if the dose is the same, regardless of quality (Chapter IX). That is to say, the degree of reaction as the result of the administration of H1¼ S. D., unfiltered, is the same regardless of the length of the spark gap. This is true for a spark-gap range from 9 down to 3 inches. One and two-inch spark-gap lengths have not yet been tried.

Experiments with *x*-rays of varying quality in the treatment of symmetrical cutaneous eruptions so far seem to indicate that the therapeutical result is much the same regardless of the penetration (wave length) providing the dose is the same. In other words, the therapeutical effect in superficial conditions seems to depend more upon quantity than upon quality. Additional experimentation and corroboration are necessary, however, before this opinion can be accepted.

It is curious how little difference there seems to be in the biological and therapeutical action of electromagnetic vibrations of various wave lengths so long as the wave lengths are within the range as represented by "soft" *x*-rays and "hard" gamma rays from radium. The effect seems to be due to absorption, *i. e.*, quantity instead of quality. It is true that short wave lengths are less readily absorbed than are long wave lengths, but they are absorbed and when quantity is sufficient the effect seems to be the same regardless of quality. We are discussing surface effects, not the effect at any given depth. The various wave lengths comprising the ultraviolet rays and visible light exert different actions on organic life but with the very short wave lengths, as represented by *x*-rays and gamma rays, the various wave lengths appear to differ only in their ability to penetrate matter.

These opinions are based largely on clinical observation and practical methods of estimating quality and quantity, both of which are inaccurate. After the pure scientists have had sufficient time to study the physical, biological and therapeutical action of *x*-rays and gamma rays of various wave lengths it is possible that present opinions will undergo considerable change.

It is important for the beginner to realize that radiodermatitis of all degrees can be produced by any type of radiation used in practice. In the case of filtered radiation, for reasons already explained, the quantity necessary to evoke cutaneous inflammation is much greater than is the

case with unfiltered radiation, but if quantity is sufficient the superficial effect will be much the same. It is a well-known fact that the pioneer roentgen operators developed *x*-ray sequelæ on the unprotected skin of the face and especially the hands. It is the general opinion that sequelæ never developed on the parts of the body protected by the clothing. Several years ago the writer had the opportunity of examining the bodies of several of these unfortunate martyrs to science. In instances where the individual had been sufficiently exposed not only were the sequelæ noted on the exposed parts but they were present, also, on various parts of the body that were always covered with clothing.

Effect of Radiations on Lesions at a Distance.—It occasionally happens that when treating one or a few lesions of an eruption, other unexposed lesions will undergo involution. Sibley, Fox and others aver that this is a common phenomenon. The author has not found this to be so. Occasionally one sees several common warts disappear as the result, apparently, of the irradiation of one lesion. This also happens occasionally in the treatment of other diseases such as psoriasis, lichen planus, acne vulgaris, mycosis fungoides and even multiple basal-cell epitheliomata. The same phenomenon has been noted when other forms of treatment have been employed. In this connection it must be admitted that all these affections, especially psoriasis, lichen planus and mycosis fungoides, occasionally undergo rapid spontaneous involution. At times all the lesions disappear, sometimes rapidly, at other times slowly. Again, certain lesions will disappear leaving the remainder of the eruption unaltered. The author has on many occasions irradiated one or a few lesions of a generalized eruption and very rarely was any influence observed on the remainder of the eruption. From the evidence at hand it must be conceded that the involution of a more or less generalized eruption as a result of the irradiation of one or two lesions is at least uncommon.

Radium Versus Roentgen Rays.—There appears to be little if any difference between the biological and therapeutical action of *x*-rays and gamma rays of radium. They seem to be equally efficacious, regardless of the disease, providing conditions are as suitable for the one as for the other. Gamma rays can be used in locations that are inaccessible to *x*-rays—mouth, nose, vagina and external auditory canal. Radium can be placed in needles which in turn are inserted into a tumor. Small, suitably screened radium applicators can be placed all over and around and even into a large superficial growth. And in many other ways radium can be so manipulated as to obtain a better result than could be had with the *x*-rays; especially is this true in institutions where emanation is used. On the other hand the *x*-rays are more suitable and more efficient in generalized dermatoses, or for the treatment of diseases that cover large areas. For various practical reasons radium is more suitable in one case while *x*-rays will be found more suitable in another. Time consumption is an important factor. Any practical

amount of filtered *x*-rays can be given in a few minutes if so desired. The time of exposure for gamma rays will depend upon the amount of radium in the applicator—it is likely to be hours. Expense is another item. The dermatologist can get along with from two to ten thousand dollars worth of radium providing that he also has an *x*-ray equipment.

There is some difference between the results obtained with the beta rays as compared with *x*-rays and gamma rays. Superficial cancer will disappear at times under the influence of beta radiation after failure with *x*-rays. The elevated type of nevus vasculosus disappears in a most astonishing manner following applications of beta rays of radium. The author has never seen such rapid involution in angioma subsequent to roentgenization. Beta rays also appear more efficacious in cavernous nevi and leukoplakia. They are certainly preferable in the treatment of keratoses subsequent to radiodermatitis and perhaps, too, in the various types of senile keratosis. There is some doubt about lupus erythematosus—beta rays are probably more efficacious. In all other diseases the effect of the two agents seems to be very much the same.

Gamma rays are more penetrating, *i. e.*, less readily absorbed than are *x*-rays, therefore they possess an advantage in the treatment of very deep lesions.

Radiologist and Dermatologist.—Dermatologists have not been sufficiently progressive. Ten or twelve years ago nearly every dermatologist possessed an *x*-ray equipment, although few of them knew much about the subject of roentgenology. They failed to keep pace with a young, vigorous, progressing science and finally discovered that roentgenology had evolved into a highly specialized and complex subject. Furthermore, even the *x*-ray treatment of the diseases of their own specialty had been transferred to the pure roentgenologist, men who were *x*-ray experts but who had little if any knowledge of dermatology. Between the technical errors of the dermatologist and the diagnostic errors of the roentgenologist the evolution of superficial roentgenology suffered considerable retardation. Even today the subject is neglected by a large proportion of dermatologists of this country. There are very few medical colleges that give the student a reasonable conception of the advantages and limitations of dermatoroentgenology. Dermatologists have simply been too lethargic, too indifferent and too mercenary to become and to remain modernized in this rapidly changing and ever progressing field.

It is difficult to resist the temptation of reminding dermatologists that they are losing control of syphilology for the same reasons. If this retrogression continues dermatology will indeed become a minor specialty. It is time for dermatologists, especially the younger practitioners, to develop more energy and efficiency. Many young men enter the field of clinical dermatology because it offers a path of slight resistance and an easy although not always a lucrative field. Dermatology, if it includes histopathology, syphilology and radiology, is a difficult specialty to master and one that is worthy of great minds.

Every dermatologist should be well acquainted with the possibilities and limitations of roentgen therapy and radium therapy. He should recognize reactions and sequelæ and understand the reason for them and how they may be avoided. He should understand the biological action of the radiations, and he should know which diseases respond readily to small doses and which require strong applications. Otherwise how can he work in collaboration with the roentgenologist? Most roentgenologists know very little about dermatology and they are, as a rule, very grateful for help and advice. The ideal, however, is for the dermatologist to be his own radiologist. The fundamentals of modern technic can be acquired in a short time but one must not stop here. Every person who prescribes *x*-rays, or radium for use on the human organism should endeavor to learn all there is to know relative to these agents and the study will include history, physics, electricity, biology, technic, etc.

Equipment.—Equipment will depend, naturally, upon the type of work to be done. A few specialists and some institutions possess a modern *x*-ray equipment for both light and heavy work and a gram or more of radium from which is obtained the emanation used for treatment. Most physicians find it necessary to begin in a modest manner and as a rule they are unable to purchase both *x*-ray apparatus and radium applicators. If it is necessary to choose between the two agents, *x*-rays should be the selection. A 2 K. W. interrupterless transformer, a Coolidge tube and the various essentials, such as tube-stand, table, etc., will answer most requirements. The cost of such an outfit varies considerably and depends largely upon industrial conditions. The cost has been as low as $700 and as high as $1500. The above equipment will give perfectly satisfactory results in deep therapy but if one is contemplating doing much heavily filtered work a 10 K. W. transformer and two or more Coolidge tubes are advisable (see chapter on *X*-ray Apparatus).

Radium should be acquired as soon as possible. For cutaneous diseases good results can be obtained with one full strength flat applicator about the size of a postage stamp. It is preferable, however, to have three or four applicators of various sizes and shapes (see chapter on Radium Technic).

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CHAPTER XX.

DISEASES DUE WHOLLY OR PARTLY TO PYOGENIC ORGANISMS.[1]

THE diseases in this group that are treated more or less successfully with *x*-rays and radium are:

1. Acne Vulgaris.
2. Rosacea.
3. Rhinophyma.
4. Acne Varioliformis.
5. Sycosis Vulgaris.
6. Furunculus.
7. Carbunculus.
8. Paronychia.
9. Miscellaneous.

ACNE VULGARIS.

Most dermatologists and roentgenologists agree that *x*-rays constitute a specific for acne vulgaris. While *x*-rays will permanently cure the majority of cases of this affection the use of the word specific is not advisable.

There are a number of clinical varieties of acne vulgaris and a knowledge of the effect of roentgenization on the various clinical types of the disease is necessary in order to properly select patients for treatment with roentgen rays.

Clinical Types.—All types of acne vulgaris have certain features in common. The disease is most commonly encountered at or about the age of puberty. It is very common in adolescents; it is less common, but not uncommon in adults. The site of predilection is the face. It very frequently attacks the back, the back and sides of the neck, the chest, shoulders and arms. The lesions consist of comedones, papules, pustules and nodules.

Comedo.—Comedo constitutes a clinical type of acne vulgaris in which the lesions consist of blackheads with perhaps a few papules and pustules. The skin is likely to be excessively oily (seborrhea oleosa). This type is amenable to irradiation.

Acne Papulosa.—Papular acne, like comedo, is supposed to be due to a low grade inflammatory reaction to the acne bacillus. It consists of comedones and papules situated at the follicular orifices. There is usually considerable oily seborrhea. This type responds well to roentgenization.

Acne Pustulosa.—In this type of acne vulgaris there is a rather acute reaction to the staphylococcus and acne bacillus with the formation

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

of numerous, small follicular pustules. Acne pustulosa is seen more commonly in young females with a fine textured, delicate and highly colored skin. This type will not tolerate as much irradiation as will the more chronic forms of the affection and the results are not likely to be as rapid.

FIG. 91.—Comedo before *x*-ray treatment.

FIG. 92.—Same patient shown in Fig. 91, after 12 fractional applications.

Acne Erythematosa.—Erythematous acne is seen mostly in females who have gastro-intestinal or menstrual disturbances. It consists of comedones and superficial pustules and more or less erythema of the entire face and at times the back and chest. This type is likely to be associated with marked remissions and exacerbations. *X*-rays are not well tolerated and should be applied cautiously.

Acne Indurata.—In this type the disease is usually of long standing; the pustules are large and deep seated, frequently indolent and cystic. The skin is likely to be sallow and excessively oily. Disfiguring scars are present. The skin in this type will support relatively large doses and the promptness and permanency of the splendid results constitute one of the most striking achievements of roentgen therapy.

Advantages of Roentgen Treatment.—While it is true that the *x*-rays are the most important and most efficacious therapeutic agent we have for the management of acne vulgaris, yet this method of treatment has been and is being abused. The abuse lies in the lack of proper care in the selection of cases, the administration of excessive dosage, and the failure to recognize and overcome the internal etiological factors.

It is neither necessary nor advisable to treat every case of acne vulgaris with the *x*-rays. The proper application of various internal and external remedies together with hygiene will suffice to cure a great many if not the majority of cases. While such treatment will cure a small percentage of cases in from three to six months, it usually requires from eight months to two years. It is difficult to obtain the complete coöperation of the patient in carrying out the campaign of home treatment. Details are neglected. Applications of sufficient strength to accomplish any good are avoided. If improvement does not occur quickly the patient is apt to become discouraged and to neglect the treatment, or other physicians are consulted.

The *x*-rays, if properly applied and combined with other means of combating the disease, offer a treatment that is associated with safety and prompt and permanent cure. It is possible to cure a case of acne vulgaris in one or two treatments by giving at one sitting a quantity sufficient to effect an erythema. Such treatment, however, cannot be too severely criticized and condemned. Fractional treatment applied in a manner that is absolutely safe, will effect a permanent cure with a high degree of certainty in three or four months, providing that the patient receives proper medical advice and treatment. Roentgen treatment obviates the necessity of using local remedies that are temporarily disfiguring and troublesome. While such treatment necessitates more frequent visits and a little additional expense, the certainty of a speedy and permanent cure, together with the absence of unpleasant local remedies, is ample reason in the minds of the patient and physician for the institution of roentgen therapy.

The *x*-rays produce a cure as a rule in from one-quarter to one-half the time required for well-applied dermatological treatment. The

percentage of cures with x-rays is much higher than with any other form of treatment. It is very close to 98 or 99 per cent. Furthermore, the percentage of relapses are small; if proper precautions are taken they will not be greater than 5 or 6 per cent.

Fig. 93.—Acne indurata before roentgenization.

Fig. 94.—Same patient shown in Fig. 93, after 12 fractional x-ray treatments.

Indications for Roentgen Treatment.—The principal reasons for instituting roentgen treatment in acne vulgaris are to obtain a speedy and permanent cure and to avoid the use of unpleasant local applications. In this connection there is another important point. In types of acne vulgaris such as acne indurata, where the disease is racalcitrant to dermatological treatment, and which consists of deep-seated, destructive lesions, every additional week of the disease means a few

more scars. Unless such cases are cured promptly the scarring is exceedingly disfiguring. If, therefore, a case of acne vulgaris does not improve with reasonable promptness under dermatological remedies, and especially if the lesions are causing scars, the immediate institution of roentgen therapy is indicated. Even in the absence of scarring it is not proper to allow the disease to continue for many months because in such instances the skin is likely to be coarse and oily. Therefore it may be said that if acne vulgaris does not steadily improve under the influence of dermatological treatment *x*-rays are indicated.

The practitioner might well ask, if *x*-rays as used in acne vulgaris constitutes a safe and certain method of treatment, why not apply such treatment in every case? The answer is that the dermatologist, who happens to be an expert roentgenologist, does employ the *x*-rays in the majority of his cases of acne vulgaris. It will not do, however, to establish a precedent of this kind because, first, it is possible for the expert dermatologist to cure the disease without the aid of the *x*-rays and, second, because in some hands the *x*-rays do not constitute a perfectly safe method of treatment.

Not only must one know when to use the *x*-rays but he must know how to use them. The treatment may be employed to advantage in all the chronic types but it should be delayed in the acute types until the acute symptoms have subsided. Furthermore, one must know when to discontinue the treatment. To completely cure the disease, *i. e.*, to prevent the appearance of even an occasional lesion, might in many instances require irradiation to the point of injury to the skin. Such treatment is unnecessary and inadvisable.

Menstrual acne, where there is an outbreak of lesions at about the time of the menstrual period and very few lesions between the periods, can be cured by means of *x*-ray treatment it is true, but such cases are recalcitrant and if one persists in depending largely or wholly on the *x*-rays the skin may be visibly injured.

Very mild cases of acne, patients who always have a very few comedones and an occasional pustule, are more stubborn, as a rule, than are the more severe examples of the disease. *X*-rays must be employed cautiously in such cases and if the disease is not arrested in three or four months it is advisable to depend upon some other form of treatment.

The so-called seborrheic acne is a troublesome type. The eruption consists of very few comedones, an occasional pustule, numerous nodules and excessive oiliness. Here, too, the tendency is to depend too much on *x*-ray treatment and persist too long in its use.

After acne vulgaris has disappeared there may still be some oily seborrhea, a very few comedones and a coarse skin due to large follicular orifices. It is preferable that some treatment other than *x*-rays be applied to improve or cure such conditions.

It is important to realize that the *x*-rays alone should not be depended upon for a cure excepting in a few cases. The main treatment is constitutional, the *x*-rays simply being one of the local remedies.

Supporting Treatment.—As we have seen it is possible to cure acne vulgaris with the x-rays without any other treatment. But such a procedure is not advisable. The object should be to effect a prompt, complete and permanent cure with as little x-ray treatment as is possible. This can be accomplished only by searching for and overcoming the cause, and the etiological factors vary in different cases. They are both local and constitutional. It may seem the intention of the author to present acne vulgaris entirely from a dermatological standpoint. It is not within the scope of this book to teach dermatology, but it is of the utmost importance that the reader appreciate that in order to obtain the desired result in this disease with the x-rays, and to effect this result without injury, one must possess and use a broad knowledge of its cause and management.

Systemic Treatment.—In every case of acne vulgaris, in addition to x-ray treatment and regardless of the cause, there are rather definite routine rules to follow.

From the diet should be eliminated candy, pastry, soda water, ice-cream, chocolate, rich foods, fried food, cocoa, gravy. If there is a tendency toward rosacea or if the acne is of the inflammatory type, the list should include tea, coffee, alcohol and spices. This is simply a routine diet. In many instances other foods must be eliminated.

The bowels must move freely at least once a day. If there is indigestion or intestinal troubles the alimentary canal must be attacked.

Focal infections should be sought for and corrected.

Masturbation and sexual excess must be avoided. The menstrual function and genito-urinary tract should receive attention.

Stock and autogeneous vaccines may be of service in acne pustulosa and acne indurata if properly employed. If the dose is too large or if the injections are given too frequently, vaccines may do more harm than good.

Local Treatment.—It is not advisable to employ stimulating remedies such as sulphur and mercury ointments, lotio alba, resorcin lotions, etc., in conjunction with x-ray treatment. A 10 per cent. ointment of zinc oxide may be used with advantage. The affected parts should be washed daily with soap and water. It is permissible to use a strong soap such as tar soap. It is advisable to remove the more conspicuous comedones and evacuate the larger pustules at each visit. If efforts in this direction are too strenuous, however, the disease may get worse.

It is well to pay attention to the scalp, especially in the seborrheic type of the disease. If the scalp shows evidence of pityriasis simplex, pityriasis steatodes or seborrhea oleosa, it should receive proper treatment.

Ultraviolet rays and excessive exposure to sunlight are not advisable while the patient is receiving x-ray treatment.

Relapses.—In spite of every precaution relapses will occur. The percentage varies among different roentgenologists but it should not be greater than 5 per cent. As a rule a relapse denotes some important

internal factor has not received proper attention—masturbation, intestinal auto-intoxication, faulty diet, etc. A relapse may occur within a few months or not for a year or two. As a rule they are very mild but occasionally the relapse may be much worse than the original attack. Ordinarily the second attack will respond promptly to another course of treatment but cases are met with where the relapse will not yield to roentgenization. In such instances it is very unwise to persist in the use of the *x*-rays.

The author had two patients of unusual interest. They were both young girls apparently in good general health. One patient had a very severe acne indurata of the face, chest, arms, neck and back. The disease was clinically cured in four months. Six months later the patient returned with the most violent acne the author has ever seen. The face was a solid mass of confluent pustules—a pyoderma. The patient at this time was anemic and had a low blood-pressure. Rest in bed and the local use of soothing and antiseptic applications overcame the acute inflammatory symptoms. *X*-ray treatment was then tried without effect. The patient finally recovered under the influence of hygiene, and local and internal remedies.

The second patient had a mild acne indurata which disappeared in the usual length of time under the influence of combined treatment. A few months later she had an attack of acne erythematosa. After the acute symptoms subsided *x*-rays were administered but they failed to effect the desired result. An *x*-ray examination of the abdomen revealed a chronic appendicitis. Appendectomy was followed by a prompt and permanent cure.

Technic.—The author prefers and advises fractional treatment; H$\frac{1}{4}$ S. D. applied once weekly to the affected parts. Most patients will tolerate such treatment over a period of four months without the slightest reaction or atrophy. A course of sixteen treatments will suffice in most instances. In stubborn cases, in the absence of erythema or wrinkling of the skin, it is permissible to continue the treatment for two additional months. If a cure is not effected in six months it is advisable to discontinue *x*-ray treatment.

A few patients will not tolerate this dosage. Low toleration is encountered in acne pustulosa and acne erythematosa. Also in young females with a fair, fine-textured, highly-colored skin. In such instances subfractional treatment (H$\frac{1}{8}$ S. D. once weekly) is indicated.

Many patients with acne indurata, comedo, seborrheic acne, especially persons with dark, coarse skins, will tolerate and should receive larger doses. The maximum fractional dose may be considered as H$\frac{1}{3}$ S. D. applied once weekly.

Patients who live at a distance and for this reason or for any other reason cannot make frequent visits, may receive semi-intensive or subintensive treatment—H$\frac{1}{2}$ S. D. every two weeks or H$\frac{3}{4}$ S. D. every three or four weeks. It is inadvisable to give intensive treatment to the face (H1 S. D.). Such treatment may in some instances

be applied to the back, arms and chest, but as a routine it is preferable to use smaller amounts.

In all cases the operator should watch carefully for the slightest evidence of erythema and at the slightest sign of such occurrence the treatment must be interrupted for two or three weeks and then recommenced with smaller doses. Also the skin should be watched very carefully for evidence of atrophy. The slightest amount of wrinkling, usually first noticed on the chin and cheeks near the mouth, calls for immediate cessation of treatment.

As a routine, it is customary to make two exposures to the face at each sitting. The anode is placed directly over the outer end of the zygoma of first one side of the face and then the other side. With the patient in the recumbent position the face is placed so that the plane of the irradiated surface is a little less than at right angles with an imaginary line extending from the anode to the skin. This will allow the radiation to spread over one side of the face and the side of the neck. The oblique rays from the two exposures will overlap on the forehead, nose and chin. While this method does not provide equal dosage over the entire face, it answers practical requirements.

In some instances it is preferable to make three exposures—one over each zygoma and one with the anode directly over the nose (full face). When this is done the plane of the face should be at right angles to the perpendicular for the lateral exposures. The dose for the sides of the face is $H\frac{1}{4}$ S. D. and that for the front of the face is $H\frac{1}{8}$ S. D. The skin-target distance must be the same for each position.

When treating the face, the eyes, eyebrows, scalp and ears must be protected with lead foil or other suitable material. It is not necessary to protect the lips.

If the chest is affected it may be left unprotected and the oblique rays from the face treatments will often suffice for the treatment of the chest. If not, then the chest should be protected when treating the face and separate exposures made to the chest. If the eruption is limited to the chest one exposure with the anode over the center of the sternum will suffice, care being taken to shield the face. If the eruption is on the anterior surfaces of the shoulders and arms two exposures are necessary, the anode being placed half way between the nipples and the anterior axillary folds, first on one side and then on the other side. The arms are placed alongside the thorax in such manner that their anterior surfaces will be on a level with the anterior surface of the chest. The oblique rays are allowed to overlap at the center of the chest. The face must be protected. Occasionally it is necessary to give separate exposures to the external surfaces of the arms.

Two exposures will usually suffice to cover the upper back, the back of the neck and the posterior surfaces of the shoulders and arms. The anode is placed one or two inches mesially to the posterior axillary folds; the arms are held against the sides of the body; the scalp is covered with lead foil. The oblique rays from the two exposures are allowed to spread over the back and the nucha.

Possible Dangers.—With caution, good judgment, and modern technic there is little if any danger of a first degree reaction. Without an erythema it is exceedingly doubtful if it is possible for telangiectasia to develop. In the *x*-ray treatment of over 1000 cases of acne vulgaris the author has not had a single example of radiodermatitis or telangiectasia.

If the treatment is continued for a long time (over six months) without intervals of rest, there may develop slight wrinkling and dryness. The dryness usually disappears in a few months due to regeneration of the appendages but wrinkling is more likely to be permanent. In the author's series of cases slight wrinkling was noted in ten patients. These were severe and badly scarred cases of acne indurata that required considerably more than the routine amount of treatment. The wrinkling was so slight that it was not noticed by the patients. While atrophy to the point of visible wrinkling will occur in any person if the treatment is continued for a sufficiently long time, or if the doses are of sufficient size, yet idiosyncratic tendencies in this respect must be admitted. For this reason the operator should study the skin carefully at each visit. Skin that has a low toleration can often be detected during a course of treatment by its irritability. It will be found to react more markedly to friction, to heat, to light, to emotional excitement, etc., than it did before roentgen therapy was instituted. In such instances the dose should be made smaller and a longer interval allowed between treatments.

It has been claimed that the *x*-ray treatment of acne vulgaris causes at times a growth of hair. It is a fact that a growth of down is occasionally seen subsequent to the *x*-ray treatment of acne. But it is seen just as frequently in cases of acne that have not been treated with the *x*-rays. No one has noticed a growth of hair following the *x*-ray treatment of psoriasis, eczema, mycosis fungoides, leukemia, epithelioma and various other diseases. The question of the hair-growing powers of the *x*-rays is discussed at some length in Chapters XVIII and XXVI. Suffice it to say here that hypertrichosis following acne vulgaris is probably due to the disease itself, enhanced perhaps, by the use of various stimulating remedies such as sulphur, mercury, resorcin, etc. There is no evidence to prove that irradiation of acne vulgaris causes or favors a growth of hair.

Pigmentation or tanning is not a serious result of irradiation but when occurring on the face it is disfiguring and sometimes it is so annoying from a cosmetic point of view that patients refuse to continue roentgen treatment. Excessive pigmentation occurs in a small percentage of cases and may consist of freckles or a diffuse tanning. Rarely it is very marked and results from a few mild applications. There is no way to avoid this idiosyncratic tendency. It is not a contra-indication to *x*-ray treatment but the patient may prefer another form of treatment. At times the pigmentation will disappear in a few weeks subsequent to cessation of *x*-ray treatment. In some instances, however,

several months and even a year or two is required for complete disappearance of the discoloration. (For the treatment of this condition see Chapter XV.)

Filtration.—Filtration in superficial affections is discussed in detail in Chapters XI and XIX. Suffice it to say here that the author has tried both filtered and unfiltered rays in acne vulgaris and insofar as can be determined the result is exactly the same. However, there is no harm in employing a filter and there may be certain advantages. The author does not use a filter in treating acne vulgaris but he does not advise against its use for this purpose.

Radium.—With the exception of technic, what has been said relative to the *x*-ray treatment of acne vulgaris may be applied to radium when used for the same purpose. If radium is employed the applicators should be so screened that only the gamma or the penetrating beta rays are used. The applicators possessed by the average dermatologist are not suitable for the treatment of such extensive surfaces, but large flexible applicators containing radium tubes or emanation tubes may be used for this purpose. The result should be the same as with the *x*-rays. Wickham and Degrais report cures of acne vulgaris with gamma rays of radium. They divided the face into numerous areas and exposed each area one hour every second day for a week. The cure was effected subsequent to a second series of treatments. Other cases were treated by leaving the applicators in place all night.

It is doubtful if radium therapy will ever equal roentgen therapy in point of facility, flexibility, economy and, therefore, in therapeutic efficacy in the treatment of acne vulgaris.

ROSACEA.

Roentgenization is of doubtful value in pure rosacea, *i. e.*, telangiectasis and diffuse erythema.

When combined with acne vulgaris, or with acneiform lesions and oily seborrhea, as it usually the case, the *x*-rays offer perhaps the best means of obtaining a prompt and permanent cure. The acneiform lesions involute and the sebaceous glands become less active. With the disappearance of the pustules there is less congestion of the affected parts.

Like acne vulgaris, rosacea is due to internal disturbances, usually of the gastro-intestinal canal, therefore it is not advisable to depend upon the *x*-rays alone for a cure. As a routine the system of interdictions given on page 309 should be followed. It is very important that tea, coffee, alcohol and spices be prohibited. The bowels must be carefully regulated. With proper attention to diet, hygiene, and the correction of underlying causes, very severe types of rosacea can usually be cured by fractional treatments in three or four months. In spite of the erythema and inflammation, the skin affected with rosacea usually tolerates the *x*-rays very well.

While the patient is under x-ray treatment it is not advisable to employ the strong ointments and lotions that are usually prescribed for rosacea. Multiple scarification and electrolysis, for the purpose of destroying dilated capillaries, is permissible and advantageous. Soothing lotions and ointments (zinc oxide ointment—calamine lotion) are beneficial and are gratefully received by the patient.

Rosacea is limited to the so-called flush centers of the face—nose, chin, mesial portions of the cheeks and the lower and middle parts of the forehead. The technic as described under acne vulgaris may be used in the treatment of rosacea—two exposures, one for each side of the face, the oblique rays being allowed to overlap at the center of the face; or one exposure may be made to the center of the face with the anode directly over the nose. If the affection is limited to the nose the rest of the face should be shielded and an exposure made to each side of the nose. In this instance, in order to avoid too much overlapping of the radiation on the bridge of the nose, the plane of the lateral surface of the nose should be at right angles to a line extending from the skin to the anode.

Hypertrophic rosacea is a sort of borderline between rosacea and rhinophyma. It may be benefited by roentgenization especially if there are many pustules. For a complete cure, however, it is necessary to resort to other forms of local treatment and to correct underlying causative conditions.

RHINOPHYMA.

The x-rays seem to be of very little real service in rhinophyma. The result will depend upon local conditions. Acneiform lesions will disappear and the sebaceous glands will become smaller and less active. The cure of rhinophyma, however, requires other forms of local treatment including surgical measures. Schultz was unable to obtain an appreciable reduction in the size of rhinophyma with as many as six intensive applications. Freund had a somewhat similar experience. On the other hand Streubel reports a complete cure of a case of rhinophyma with x-rays alone.

Radium.—Radium will accomplish the same results in rosacea and rhinophyma as will the x-rays. In the case of rosacea the extent of the involved surface is a handicap to those possessing only one or two flat applicators. It is possible that the beta rays of radium might be more efficacious in rhinophyma than are the x-rays. The author has not used radium in this disease. Wickham and Degrais report favorable results with the gamma rays of radium in both hypertrophic rosacea and rhinophyma. Finzi states that rhinophyma "is very readily influenced by radium rays and the nose can be brought back almost to a normal condition."

ACNE VARIOLIFORMIS.

It is difficult to estimate the true value of the *x*-rays in acne varioliformis. The disease usually yields readily to mercurial and sulphur ointments, although recurrences are common. Furthermore, while running a long course, there are remissions, periods of latency and exacerbations. The author has treated 10 cases of this affection with the *x*-rays. In every instance the eruption subsided in one or two months under fractional treatment. In 2 cases there was a recurrence which again disappeared under roentgenization. So far as is known the other patients remained well. The impression gained is that roentgenization appears to lessen the tendency toward recurrences. This opinion, however, is not based on statistics—it is simply an impression. Only one literary report dealing with the *x*-ray treatment of acne varioliformis has been found. Allen, in 1904, states that "in patients treated with *x*-rays, the well-known tendency to recur seems to be removed or at least decreased."

Acne varioliformis affects mostly the forehead and scalp, occasionally the nose. The technic of application will depend upon the distribution of the eruption. If limited to the nose, this organ is irradiated as explained under the heading of rosacea. If the forehead is involved the hairy parts and the face are shielded and weekly fractional doses applied with the anode placed over the center of the forehead. If the lesions are situated in the eyebrows and on the anterior scalp, these parts are left unshielded and subfractional doses administered once weekly. If the eruption is scattered over the scalp the entire head is irradiated by the Kienböck-Adamson method (Chapter XXI) the dose being H⅛ S. D. once weekly for four treatments. It is unsafe to administer more than H½ S. D. in a month, otherwise a defluvium of scalp hair may result. This amount will usually suffice for a cure; if not, there must be an interval of rest of one month before further irradiation. If the eruption involves the face and scalp, the former may be left unshielded while applying the Kienböck-Adamson method.

SYCOSIS VULGARIS.

Bowen was one of the first if not the first physician in this country to report the successful use of the *x*-rays in sycosis vulgaris. He reported the cure of 11 cases in 1903. The literature contains a very large number of articles dealing with this subject. The following exposition of roentgen therapy in this disease is based on personal experience and a knowledge of the literature.

The results obtained with roentgen rays in sycosis vulgaris range from brilliant to poor. The author has seen long-standing cases of this affection (ten to fifteen years' duration) permanently cured as a result of a few fractional exposures. Judging from personal experience a minority of cases can be cured by fractional treatment in a month or

two without epilation. The majority will require a defluvium. Occasional cases demand permanent alopecia and at times even a permanent alopecia will not effect a cure.

FIG. 95.—Sycosis vulgaris before *x*-ray treatment.

FIG. 96.—Same patient shown in Fig. 95, after *x*-ray treatment. In this case it was not necessary to cause temporary alopecia. The affection was bilateral and symmetrical.

Recurrence in this affection is common but as a rule the relapse will yield to further roentgenization.

Technic.—The technic of application is the Kienböck method which is described in detail on page 347. This technic is applicable to cases where the affection is limited to the bearded region. Rarely the disease affects the eyelashes, eyebrows, anterior scalp hair line, axillæ and pubes. In such instances these parts are treated separately.

Eyelashes and Eyebrows.—The lids are closed and covered with a thick coating of a 50 per cent. ointment of zinc oxide or bismuth subnitrate. Or better still, properly patterned pieces of lead foil may be fastened to the lids with zinc plaster. The remainder of the face is shielded and the radiation is applied first to one exposed region and then to the other.

Anterior Hair Line.—The face, scalp, ears and neck are shielded. Two exposures are made with the anode centered over the temporal regions. The oblique rays are allowed to overlap at the center of the anterior hair line.

Axillæ.—The patient lies on his back and places his forearm under the head. All parts excepting the axillæ are shielded. An exposure is made first to one side and then to the other side with the anode centered over the center of the axilla. In the position given the axilla is a little concave, but with the anode at a distance of eight inches dosage will be sufficiently uniform over the affected area.

Pubic Region.—The unaffected parts are shielded. One exposure with the anode placed over the center of the pubic region will usually suffice to cover the affected area.

Dosage.—Inasmuch as fractional treatment without defluvium will suffice for a cure in many cases it seems advisable to first try such treatment. H¼ S. D. once weekly for five or six treatments will answer the purpose. If the desired result is not obtained it becomes necessary to depilate. To produce a defluvium of the bearded region without the advent of at least a mild first degree radiodermatitis is a difficult matter. It is almost impossible with intensive treatment. It usually requires at least H1 S. D. to effect defluvium and this quantity is very likely to evoke an erythema of the skin of the face. As a matter of fact it usually requires H1¼ S. D. administered at one sitting, to cause the hair of the male beard to fall out. It is unwise to administer doses of this size to the face for this purpose because of the danger of an *x*-ray erythema. The reason for this attitude is that even a mild *x*-ray erythema may be followed in several months by a very disfiguring telangiectasia.

There are two ways in which the latitude of safety can be increased. Filtration is one method. With filtered radiation one has a little greater latitude between the amount necessary for epilation and the amount that will effect an erythema. The hair may fall out as a result of H1½ or H1¾ S. D. 3 mm. Al., but it is likely to require H2, and this amount may cause a mild reaction in some persons.

The other method has personal preference. It consists of applying H¼ S. D. unfiltered, every five days for four doses, or H⅓ every seven days for three doses. The hair usually falls out one week after the last treatment. If not it becomes necessary to continue the treatment, with the same doses and intervals, until a defluvium results. The same method may, of course, be used with filtered radiation, the doses being increased proportionately. In most instances it is possible to depilate the beard by this method without the advent of even a mild first degree reaction. But in some instances the doses have to be larger than those advised. Even in such cases the hair will fall out as a rule without signs of a reaction.

The main point is that in obstinate cases of sycosis vulgaris one is working with a quantity of radiation that is very close to that required for a mild first degree reaction, therefore the patient must be kept under close observation for signs of cutaneous irritability which often occurs when absorption is close to the saturation point. This irritability is manifested by a pronounced temporary erythema following friction, exposure to heat, light, wind, exertion, or when the head is lower than the body, or it may be coincident with emotional excitement.

If, after fractional treatment has failed to effect a cure, it is decided to push the treatment to the point of epilation, it is wise to allow a rest interval of three weeks before changing the technic.

For medico-legal reasons it is advisable to acquaint the patient with the difficulties and possibilities of the treatment. If he has tried other forms of treatment, skilfully and conscientiously administered, without success, he will usually accept the slight risk with the understanding of course that there is no alternative and that the operator will employ a modern technic, requisite skill and judgment.

In dealing with unusually recalcitrant, or relapsing examples of the affection where the treatment as above outlined has failed, the advisability of effecting a permanent alopecia can be considered.

Permanent Alopecia.—The first step is to depilate the hair with the technic already outlined. If no further radiation is administered the hair will begin to grow again in a month or two. To prevent this regeneration it is necessary to apply semi-intensive treatments (H½ S. D.) once monthly for from four to eight months and in some instances even longer.

In effecting a permanent alopecia there is little if any danger of telangiectasia, providing there is no erythema at the time of the defluvium, but there is danger of more or less wrinkling and dryness of the skin. Wrinkling will occur in some cases and not in others. There is no way to avoid this sequela with certainty and the patient should clearly understand this fact.

A man afflicted with a bad case of this most disfiguring and annoying disease, assuming that the affection has resisted skilful and intelligent dermatological treatment, will willingly sacrifice his beard and he will be glad indeed to risk the chance of atrophy and even of telangiectasia to be permanently rid of his disgusting affliction.

It is very uncommon to see sycosis vulgaris persist after permanent alopecia has been affected, but the disease has been known to exist in a modified form after the beard has been permanently lost. The explanation is that lanugo hairs are still present and may, in certain individuals, become the seat of the disease.

It should be borne in mind that severe sycosis vulgaris may effect more or less permanent alopecia, atrophy and scarring. The *x*-rays must not be blamed for sequelæ caused by the disease itself.

Supporting Treatment.—It is not permissible to allow the use of strong local applications two weeks previous to *x*-ray treatment, during such treatment and for at least two weeks subsequent to the treatment. During this period of prohibition the parts should be washed twice daily with hot water and a non-irritating soap. Shaving is permissible and advisable in mild examples of the disease but it should be done carefully. Before and after shaving the parts may be sponged with a solution of corrosive sublimate—1–5000 in 50 per cent. alcohol. The shaving cream can contain corrosive sublimate in the strength of ¼ grain to 4 ounces. In severe cases shaving is so difficult that it is preferable to cut the hair close to the skin with scissors. A 3 per cent. ointment of sulphur precipitate or ammoniated mercury may be applied at night, providing there is no evidence of *x*-ray erythema or cutaneous irritability. The author prefers to use zinc oxide ointment at night and a calamine lotion in the daytime. There is no objection to the removal of affected hairs with forceps. After defluvium a 10 per cent. ointment of sulphur or white precipitate may be used.

Vaccine treatment, tonics, hygiene and other measures to increase general resistance should by all means be given.

Radium.—With the exception of technic, what has been said relative to the *x*-rays in the treatment of sycosis vulgaris will answer for radium. The author has had no experience with radium in this disease. The extent and irregularity of the surface usually affected makes it difficult for one who has only a small amount of radium. Small, isolated areas can be handled very nicely by means of a flat applicator. Either the gamma or the most penetrating of the beta rays should be employed. The advantages and disadvantages of fractional and intensive treatment are the same as those given for the *x*-rays. Simpson, Finzi, and Wickham and Degrais have successfully treated cases of sycosis vulgaris with radium.

FURUNCULUS.

The *x*-rays are of distinct service in the treatment of recurrent boils in any given area as, for instance, the back of the neck and the axillæ. One suberythema dose will often prevent the development of new lesions. It is frequently necessary, in order to effect a cure, to depilate the parts. If this is attempted in one treatment erythema is likely to result. For reasons given elsewhere in this chapter it is desirable to avoid an erythema, especially on parts that are not covered by clothing.

Fractional doses and subintensive doses, without the advent of erythema, will often suffice for a cure. If, however, it is necessary to cause a defluvium it is preferable to do so by means of the technic and dosage explained in detail under the heading of sycosis vulgaris.

Pusey and Ormsby consider roentgen therapy a very valuable method of treatment in recurrent furunculosis in circumscribed areas. It is of course advisable to use other methods of treatment also, such as vaccines, tonics, local cleanliness, general hygiene, etc.

The author has not tried the *x*-rays in single boils or in carbuncles. Coyle has obtained remarkable results by the use of intensive filtered radiation in carbunculus. Dunham obtained prompt cures in 11 cases of carbunculus with the same technic. Ruggles confirms Dunham's work, obtaining quick cures in both boils and carbuncles. All of Dunham's 11 cases received "one full therapeutic dose with the Coolidge tube, target distance 8 inches, through 3 mm. of aluminium, with a 9-inch spark gap. This requires about 35 milliampère-minutes and gives more than 10 Kienböck units." The first night after the treatment the patient is likely to be worse but within forty-eight hours the pain will have disappeared. Sometimes the induration is gradually absorbed. In other cases the lesion softens and the contents are evacuated. Dunham cautions against allowing infection to occur in other parts of the neck. He has obtained excellent results with similar treatment in cases of streptococcic palmar abscess.

Radium.—No literature has been found dealing with radium in the treatment of boils and carbuncles. If properly used the result should be the same as that obtained with *x*-rays. In the case of carbuncles and individual boils the applicator should be heavily screened, only the gamma rays being used. When employed for the purpose of preventing the further development of lesions, the penetrating beta rays can be used.

PARONYCHIA.

The author has had a few good results and many failures with the *x*-rays in the treatment of chronic pyogenic paronychia. Ormsby has found such treatment of service. Pfahler reports the cure of a very long-standing case with twenty-five subfractional treatments over a period of three months.

Lack of experience does not permit the constructing of an exact technic. It is well to shield the fingers to within a half inch of the nail. Fractional treatment and subintensive treatment, without the production of erythema has given about the same results. It is possible that doses large enough to effect a reaction might prove more efficacious but such treatment is not advisable. In the author's hands filtered radiation has not proved superior to unfiltered radiation.

No references have been found relative to the use of radium in this affection. That radium will prove at least as efficacious as *x*-rays is a

rtainty and it is possible that beta rays will prove most efficacious. he author treated one case with the beta rays of radium. The eatment was a failure. The affection had resisted all forms of reatment including the *x*-rays.

MISCELLANEOUS.

One case of dermatitis vegetans was treated with unfiltered fractional doses without effect.

Two cases of what was thought to be chronic streptococcic lymphangitis were cured by *x*-ray treatment. In one instance the affection involved the nose, being secondary to a disturbance in the nasal passage. The eruption consisted of thickening of the skin, redness and occasional pustules. The duration was three years, during which time there were remissions and exacerbations. The affection disappeared after sixteen fractional treatments at weekly intervals. The patient also received vaccine treatment. A year later there was a recurrence. This time the affection disappeared in two months under fractional *x*-ray treatment without the administration of vaccines.

The second patient presented a palm-sized area of red, thickened skin on the left cheek. Sharp exacerbations associated with the development of numerous pustules occurred frequently. The duration of the affection was six years. Three unfiltered, subintensive doses were administered at monthly intervals. There was no improvement until after the third treatment when the eruption disappeared. The patient has remained well over a period of six years.

Chronic, indolent ulcers, supposedly of staphylococcic or streptococcic origin, are at times benefited by a few fractional applications of *x*-rays or radium—especially the beta rays of the latter.

Two cachectic patients with abscesses of the face, chest and back, associated with acne vulgaris (acne cachecticorum) were apparently greatly benefited by fractional *x*-ray treatment combined with other measures directed at the general health.

Two cases of ulerythema sycosiforme (lupoid sycosis) have been cured with three subintensive applications of *x*-rays. Allen cured a case of this disease with fractional treatment. The affection recurred in six months but again disappeared under roentgenization. The author's cases were treated four years ago. The patients have not been seen since. This disease causes atrophy and permanent alopecia, sequelæ that should not be blamed on *x*-ray treatment.

Three cases of a somewhat similar condition—folliculitis decalvans—were cured by a single epilating dose. Angle cured a case of this disease with fractional *x*-ray treatment over a period of six months. Of course, the *x*-rays had no effect on the permanent alopecia and atrophy caused by the disease itself.

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CHAPTER XXI.

DISEASES DUE TO FUNGI.[1]

Of the cutaneous affections due to pathogenic fungi the following are more or less amenable to *x*-ray and radium treatment:

1. Tinea Tonsurans.
2. Tinea Favosa.
3. Tinea Barbæ.
4. Onychomycosis.
5. Ringworm of the Glabrous Skin.
6. Actinomycosis.
7. Blastomycosis.

TINEA TONSURANS.

(Ringworm of the Scalp.)

Historical Sketch.—Freund, in 1897, was the first to suggest the use of *x*-rays in the treatment of this disease. Cures were soon reported by Schiff and Freund, Kienböck, Török, and Schein, and many others. The technic used at that time consisted in applying inaccurately estimated fractional doses two or three times weekly until a defluvium resulted. The results, at first encouraging, were negatived by the large percentage of cases of permanent alopecia due to excessive dosage.

In 1904 Sabouraud and Noiré devised a method of depilating the entire scalp at one sitting. They employed their own radiometer, a description of which will be found on page 117. The method consisted of dividing the scalp into ten or twelve areas and exposing each area to an epilating dose as estimated by means of a pastille. As each area was treated the remaining portions of the scalp had to be carefully shielded, a specially constructed metal cone, of proper size, shape and length being used for the purpose. This metal cone was called a localizer. It served to confine the radiation to a definite area and to keep the head in constant relation to the source of radiation. It also contained a receptacle at half distance for the pastille. In the course of a year or two they depilated many hundred cases with an exceedingly low percentage of untoward results.

The work of Sabouraud and Noiré was watched with no little interest by dermatologists and roentgenologists of other countries. Ringworm of the scalp was disappearing from France as a result of the new method of treatment. Naturally the method was given a trial in other

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

countries, especially in England. But the results were not favorable; the percentage of cases of permanent alopecia was too high. In France they employed static machines, in England coils were used. At first very little was known relative to pastille characteristics. Nevertheless, in spite of many difficulties and discouraging results, the English roentgenologists persisted and it was not long before their efforts were crowned by success.

Kienböck, in 1907, devised a very ingenious method of dividing the scalp into five areas. No protection was necessary excepting for the face, ears and neck. Each area was given a pastille dose. The oblique radiation from one area reinforced similar radiation from other areas thus providing equalization of quantity over the entire convex scalp.

Two years later Adamson published an excellent article in which he modified the Kienböck method and explained in a very practical manner the details of the technic. With the Sabouraud-Noiré technic it required four hours to apply the treatment to the entire scalp. Adamson's technic reduced the time to one and one-half hours.

It was still necessary to place the pastille at half distance and to use some method of fixing the head. Fixation of the irradiated part is of the utmost importance when the pastille is placed at half distance (Chapter X). The popular method of fixation was to have soft wooden pegs attached to the tube-stand. These pegs could be adjusted so as to keep the head in proper relation to the *x*-ray tube. Soft wood was utilized because the pegs were in the field of radiation and if composed of hard wood too much radiation would be lost by absorption. Hampson, in 1911, overcame these difficulties by estimating the dose with the pastille on the skin instead of at half distance.

The evolution of roentgen technic in the treatment of tinea tonsurans ends with the advent of the Coolidge tube, the interrupterless transformer and electrical methods of measurement.

Depilation of the entire scalp is accomplished today by the Kienböck-Adamson technic with the exception that estimation of the dose is by the indirect method. With modern methods a trained technician rarely requires more than one-half hour for treatment of the five areas unless the patient is very unruly. It is possible to treat the five areas in less than half of this time if necessary or advisable.

Value of Roentgen Treatment.—Ringworm of the scalp varies considerably geographically both in respect to severity of symptoms and number of cases. In localities where the affection is common and recalcitrant it is a positive menace to society. The only other successful treatment consists of daily washing, careful removal and burning of the brittle diseased hairs and applications of antiparasitic ointments. This laborious and disagreeable treatment is successful when the patient's family is intelligent and reasonably well-to-do. But even in such instances several months or a year or more is likely to be required

for a cure. Ringworm of the scalp is most common in thickly populated districts and in such localities the parents of the child have neither the intelligence nor the time to successfully combat the disease in this manner. The result is that in large cities there are thousands of children afflicted with this disease. Such children are a menace to their fellows and as they are not allowed to attend school the disease must be considered as one cause of illiteracy. This last fact is especially important when one considers that the affection in many instances continues until the age of puberty at which time the little patient is more likely to go to work than to attend school.

Roentgen treatment effects a cure in one sitting. In the majority of instances the child can return to school in a month or two. If the treatment is administered by one who is properly trained in the work there is no danger of any kind to the child. Unfortunately there are very few free clinics and not many private laboratories in this country where these patients can receive modern roentgen treatment. It is a pleasure to see that the number of physicians taking up this work seriously is increasing and it will only be a question of time when these physicians will become associated with well-equipped free clinics. It would be a splendid thing if the Health Boards of large cities became interested to the extent of equipping a clinic with modern apparatus and furnishing one or more trained technicians to work under the supervision of a dermatologist who has had roentgenologic training. Such training can be easily obtained.

It is interesting to note the results, from an economical and sociological standpoint, that were obtained in France at the very beginning of the work. At the Paris ringworm school prior to 1903, the average time required for a cure was two years. About 300 cases were hospitalized and about 110 were annually discharged cured. After the institution of roentgen therapy the cure required three months and in the first year 327 cures were effected. Estimating the cost of maintenance of a child at the school at fifty-six cents a day, the cost to the city was reduced from $400 to $56 per capita per annum. As one of the buildings containing 150 beds which had been used for ringworm cases was returned to the Health Board, the saving in the budget, valuing a bed at $2,000, amounted to about $300,000. The provincial colonies for ringworm at Romorantin, Frévent and Vendôme, with accommodation for 350 cases, were practically discontinued as all such cases were treated as out-patients at a cost of less than $1.00 per head. Somewhat similar results were noted in England, especially at the ringworm schools of the Metropolitan Asylums Board.

It is quite possible that with enforced treatment and suitable sanitation tinea tonsurans can be completely eradicated.

The author does not desire to be understood to advocate the x-ray treatment of every case of tinea tonsurans in every locality. In some geographic centers the affection is uncommon and very easily cured by other methods. Inasmuch as the affection spontaneously disappears

at puberty it is not always necessary to irradiate patients who have the disease but who are close to the age of puberty.

Preparation of Patient for Treatment.—The preparation of a patient for roentgen treatment of tinea tonsurans is of considerable importance. The most important point of all is to ascertain what treatment has been recently applied to the scalp. If irritating ointments or lotions have been used (iodine, croton oil, mercury, sulphur, chrysarobin, etc.), it is preferable to allow a period of two weeks to elapse between the last application and the roentgen treatment. If the scalp is inflamed as a result of such applications, a period of two weeks should elapse after the disappearance of the inflammation before the *x*-rays are administered. If these instructions are disobeyed a radiodermatitis or permanent alopecia may result.

The hair should be cut close to the scalp, sufficiently close to allow marking of the scalp with a skin pencil. Removal of the hair not only facilitates making the necessary marks and lines (to be described later) on the scalp but a bald head is much easier to handle than is one containing a wealth of long hair. Furthermore a heavy head of hair acts as a filter and interferes with estimation of dosage.

All crusts and scabs should be removed with soap and water. In fact the head should be washed daily with soap and water prior to the treatment.

Finally, in nervous or unruly children one or more rehearsals may be necessary before the child acquires sufficient confidence to allow the head to be placed in position and to keep it in position during the treatment. As a rule it is remarkable how well these little patients behave, but occasionally a child is encountered that tries the patience of the physician and technician to the limit of endurance.

Age of Patients.—As a rule it is impossible or at least very difficult to depilate the entire head of a child under two or three years of age for the simple reason that the patient will not remain quiet. There is no objection to treating infants if they will remain quiet. The author has depilated the entire scalp in a number of children between the ages of fourteen months and two years. In infants, on account of motion, the treatment has been confined to one or several small ringworm patches. In such instances the head is held firmly in position by an assistant and the dose administered in from thirty to sixty seconds. Fortunately the majority of patients who are brought to the clinic for treatment are between the ages of two and eight years.

Technic.—The method of marking the scalp and the angles of incidence herewith described were first advocated by Adamson. Proceed as follows: A mark is made (with a skin pencil) 2 inches inside of the hair-line above the forehead in the median line (Fig. 97). This may be designated as point A. A steel tape measure is then placed with zero on point A and stretched along the median line over the vertex to the neck. At 10 inches another mark is made—point B (Fig. 98). This will usually be about 2 inches inside of the hair-line on the back

eck, but will vary somewhat in accordance with the size of the Points A and B should be adjusted so that they are about the istances inside of the anterior and posterior hair-lines. As a of fact, A and B, in some instances, may fall exactly at the e, but this makes no difference so long as the distance between s exactly 10 inches. Point C is then indicated by a mark in the line exactly half way between points A and B (Fig. 99). On kull there is a flat surface just anterior to the occiput and point

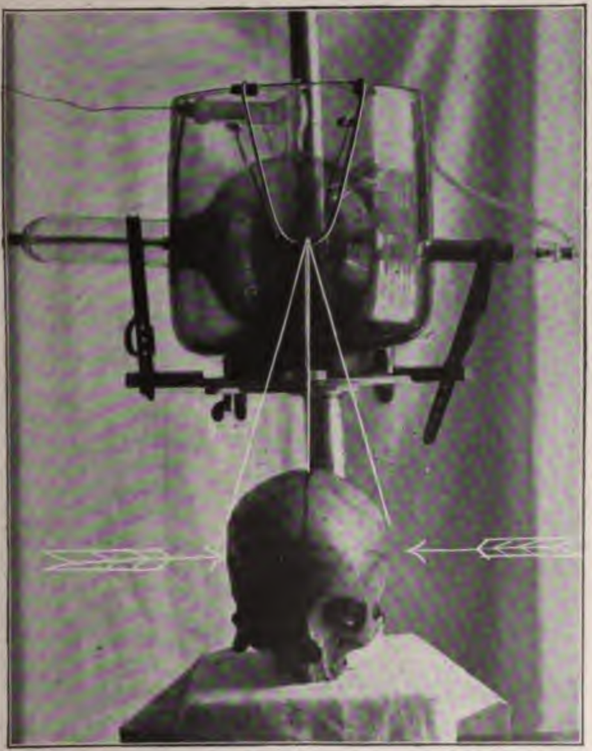

Fig. 97.—Showing angle for Point C.

fall from 1 to 1½ inches in front of the center of this area. One sist upon point C being exactly at this location and adjust A so that they will be just 5 inches anterior and posterior to C. D is then located just above and in front of the right external ry meatus (Fig. 98). The exact position of this spot is found by ring 5 inches from A, B, and C. Point E represents the same n on the left side. It is essential that each point be exactly 5 from the next nearest point.

next step is to draw lines between the various points (Figs.

97, 98, 99). This will divide the scalp into four triangular areas. The reason for this will be made clear later.

Next, each point—A, B, C, D and E—receives an epilating dose of *x*-rays in the following manner:

For point A the child lies on its back on a table. The entire face below the hair-line is protected by lead foil or other suitable material. The tube is placed with the anode exactly over and exactly 8 inches from point A (Fig. 98). It will be seen that the vertical rays will strike point A, while half of the oblique rays will fall upon the anterior portion of the scalp, and the remaining half will strike the protecting shield on the face and be wasted (Fig. 98).

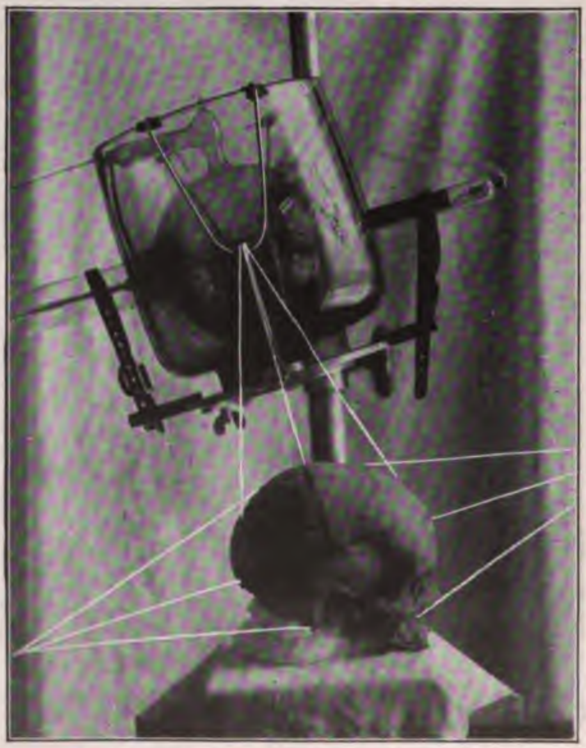

Fig. 98.—Showing angles for Points A, B and C.

Points B, C, D, and E are now to receive the epilating dose in the same manner with the following exceptions: For point C the patient may recline on a table or sit upright on a chair. No protection is required. Here the oblique rays spread over the anterior, posterior and lateral portions of the scalp. For point B, the child may lie on his side on the table or sit in a chair with his forehead resting on the table. It is necessary to protect the neck, shoulders, and back. Here half of

the oblique rays will reach the posterior portion of the scalp while the other half will spread over the shoulders and back. For points D and E the patient lies on his side on a table and the ears, face, and neck are protected. Here, as in points A and B, half of the oblique rays are lost.

It is of the utmost importance that each treatment be at right angles to every other treatment. For instance, an imaginary line drawn from the anode to point A will be at right angles to lines extending from the anode to points C, D, and E. Figs. 97, 98 and 99 will explain these angles better than words and, also, they will demonstrate that the lines drawn on the scalp between the five points aid one in quickly determining the correct angle.

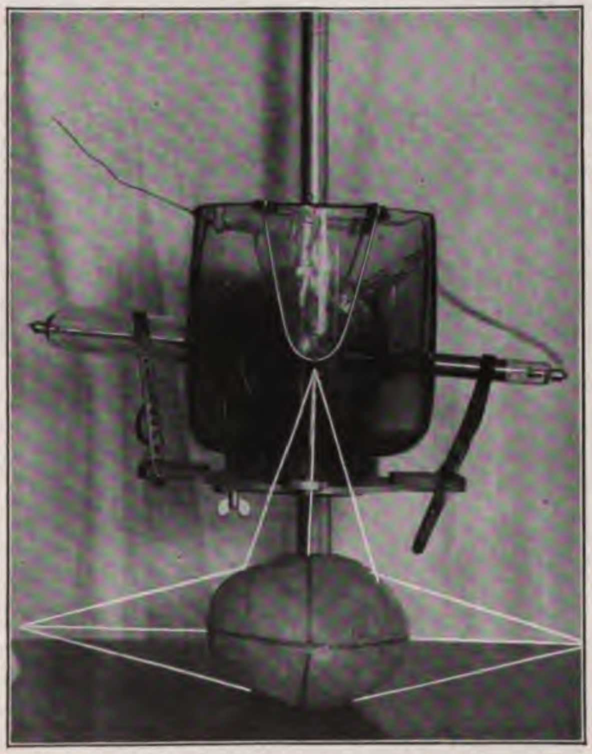

FIG. 99.—Showing angle for Point D.

A study of these illustrations will show, also, how the vertical rays strike the five points while the oblique rays from one treatment overlap and reinforce similar rays from other treatments. For instance, if a full epilating dose is administered to point E and to no other portion of the scalp, the hair will fall out over only a very small area (Fig. 100). But when similar doses are applied to points A, B, and C the oblique rays overlap and universal alopecia is the result (Fig. 101). In

FIG. 100.—Shows the loss of hair resulting from a single exposure to Point D without exposures being made to other parts of the head.

FIG. 101.—Same as Fig. 100, after the five-exposure method has been applied.

explanation it may be stated that point E, being in the field of vertical rays, receives the full epilating dose, while a point half way between E and B receives one-half of an epilating dose. But this point also receives one-half an epilating dose when point B is treated. In this way the entire scalp, when the five points have been treated, receives a full epilating dose.

On page 292 the reason for this equalization of quantity over a convex surface is explained in detail. Suffice it to say here that the law: intensity varies inversely as the square of the distance or directly as the sine of the angle, effects equalization of the dose over the entire scalp.

In practice it will be found that the size and shape of heads vary considerably. But this fact is of no practical importance. The essential features thus far are to have the exposure points at equidistance (5 inches apart), to have each exposure at right angles to other exposures, to protect only the non-hairy parts and to have the anode-skin distance exactly the same for each exposure—a distance of 8 inches is recommended.

The Dose.—There does not appear to be very much difference in the susceptibility of the scalps of children between the ages of two and twelve insofar as concerns epilation. H1, estimated by the pastille method of measurement, with the pastille on the skin, is the epilating dose. This will nearly always produce a fairly complete defluvium. Occasionally it is necessary to apply H1¼ S. D. This is a safe dose but it must not be exceeded excepting in cases where the toleration is known to be greater. It is advisable to consider H1¼ S. D. as the maximum amount that can be administered to the scalp of children between the ages of two and twelve years for the purpose of temporary alopecia. In children under two years of age and in infants the dose should be H¾ S. D. with a maximum of H1 S. D. In adults there is a wider range of toleration, depending somewhat upon the age and complexion. H¾ S. D. has been known to produce defluvium in a female blond, twenty-two years of age—a case of psoriasis. At the other extreme it required H1¾ S. D. to depilate the head of a female brunette afflicted with favus.

The epilating dose is to be administered to each of the five points in succession. The beginner is urged to be guided by Chart 12, shown on page 144. If for any reason the five areas cannot be treated at one sitting it is permissible to expose one area daily. If the intervals are greater than this the hair may fail to fall out.

Formerly it was necessary to estimate the dose radiometrically—by using pastilles or photographic paper for each exposure. Fortunately this troublesome procedure is no longer a requisite of the technic. The author and his associates have employed the indirect method of dose estimation (page 143) in this work for over five years. The heads of 600 children have been depilated without a single case of permanent alopecia. Hazen reports 225 patients treated in this manner. In one instance there was permanent baldness and in another

patient the subsequent growth of hair was sparse. Hazen was able to locate a technical error, thus supporting the accuracy of the method if properly conducted. The bad result in one patient was due to the stopping of a watch and in the other it was due to too much motion of the head.

It is remarkable how expert a technician becomes with experience. With sufficient experience it is possible to apply the treatment without clipping the hair and without making any marks on the scalp. Such procedure, however, is not advisable.

Experiments have been carried out with various qualities of radiation, even with filtered rays; the result is always the same if the dose is correct. Filtration has not been found of advantage. Various skin-focal distances have been used—6½ inches, 8 inches and 10 inches. The result is the same if the distance is the same for each exposure. The skin-target distance used by the author is 8 inches.

Margin of Safety.—The margin of safety is sufficient to cover the possible unavoidable error. As stated supra it is safe to administer H1¼ S.D., to any scalp (exceptions recorded supra). In the majority of ringworm cases it requires only H1 to effect a defluvium sufficient to cure the affection. Thus there is a margin of safety of at least H¼ S. D. As a matter of fact many if not most scalps will tolerate a dose of H1½ S. D. without injury, but the administration of this amount is unwise and unsafe unless individual toleration is previously ascertained.

Fixation of Head.—It has been found by experience that most children will hold their heads quietly during the exposure if they are properly handled. As a rule they are likely to become nervous, frightened and unmanageable if an attempt is made to fix the head by use of sand-bags, weights, and various mechanical devices. However, in some instances it is preferable to employ mechanical devices for holding the head steady. There is no satisfactory method for this purpose. Sand-bags are too heavy and bulky. A flannel roller bandage may be placed over the head and fastened to the sides of the table. Pegs of soft wood may be attached to the tube-stand, the distal ends being in contact with the scalp (Fig. 102). If such pegs are employed they must be made of very soft wood so as not to absorb much radiation. These pegs, when of proper length, keep the head at the same distance from the anode during the entire exposure. Or, if the head becomes separated from the pegs the fact is instantly noted by the operator or assistant. The head should not be placed on a soft cushion as such a head-rest does not permit sufficient stability.

One cause of restlessness on the part of the child is sparking from the lead foil used to protect the non-hairy parts. This can be prevented by grounding the lead or better still by using the protection material described on page 102. A sheet of this flexible material can be cut into three patterns—one for the forehead and anterior face, one for the side of the face, neck and ear, and one for the back of the neck and shoulders.

The same patterns will answer for every child and they will last for years. Not being a good conductor there is little if any sparking from such material.

Time, Distance, Voltage and Milliampèrage.—These factors may be anything the operator desires within reasonable limits. If the work must be done rapidly ampèrage or voltage may be increased or distance shortened. Experience has shown that for the majority of cases a working time constant of three minutes is satisfactory. It is neither too slow nor too rapid. Greater rapidity is likely to be associated with less accuracy; longer exposures try the patience of the child.

FIG. 102.—Illustrates a method of fixing the head and fixing the distance by means of soft wooden pegs attached to the tube-holder.

All factors must, of course, remain constant throughout the exposure. The only important difficulties will be associated with time and distance. The time should be kept with a stop-watch. The operator

must, so to speak, keep one eye on his milliammeter and the other on the patient's head. If the head moves perceptibly upward, downward or sidewise, the exposure must be at once interrupted. It is such interruptions that are likely to cause confusion in timing the exposure and this is the reason for the stop-watch.

Subsequent Events.—Some children exhibit a slight elevation of temperature, loss of appetite, restlessness and other symptoms of mild indisposition the day of, or the day following the treatment. These symptoms are not common and may be ascribed to the nerve strain or to a systemic reaction such as that described on page 293. In no instance have convulsions or other alarming symptoms been noted.

A week or two after the treatment there may be a very slight erythema of the scalp which subsides in two or three days leaving pigmentation. Pigmentation may develop without antecedent erythema. A few hours after the treatment, especially if lead foil has been used for protection, there may be a temporary erythema of the scalp and even of the non-hairy parts (page 214). A week or ten days subsequent to the treatment all the ringworm areas are likely to become inflamed and painful. This is especially marked in instances where the lesions are numerous and active and particularly so in the suppurative type of the affection. The child is likely, under these circumstances, to show toxic symptoms including a more or less generalized erythematous, papular or squamous eruption. None of these symptoms need occasion alarm.

A true first-degree radiodermatitis *i. e.*, an erythema developing from five to ten days subsequent to the treatment and enduring for from one to three weeks, may or may not be followed by permanent alopecia. The outcome is simply uncertain. In the majority of such instances the hair will regrow, although its reappearance will be delayed and the new growth is likely to be sparse and not of good quality. If the reaction is associated with edema or erosion (second-degree reaction) the hair in all probability will not regrow.

Ordinarily the defluvium begins about the end of the second week and is complete by the twenty-first day. It may occur a few days sooner or a few days later. As a rule, with III S. D., all the hair does not fall out. The diseased hair falls but some healthy hair remains. A complete defluvium is not necessary for a cure in the majority of cases. The author has seen cures follow very incomplete depilation. At the time of defluvium there may be a faint erythema, which disappears in a few days.

Fig. 101 shows a head that has been depilated by the Kienböck-Adamson five-exposure method. It will be noted that there is some hair remaining. The patient made a complete recovery. Figs. 103 and 104 represent a patient with disseminated ringworm before and after irradiation. Fig. 104 shows the tanning so often seen subsequent to the treatment.

FIG. 103.—Disseminated ringworm before treatment.

FIG. 104.—Same as Fig. 103, after treatment by the Adamson five-exposure method. Note the tanning of the scalp.

The hair begins to regrow in from one to three months subsequent to the defluvium. If there is no evidence of regeneration in six months permanent alopecia will be the result. The regrowth of hair is usually vigorous but at times it is sluggish. These variations depend, apparently, upon the size of the dose. It not frequently happens that the new hair is of different quality from the original growth. If the original growth was curly the new hair might be straight and *vice versa*. It may be a little coarser or a little finer in texture. Also, the color may be a little lighter or slightly darker. These variations appear to be idiosyncratic. Sometimes the new growth of hair will be less rapid in the ringworm areas than on portions of the scalp where there was no disease (Fig. 105).

Fig. 105.—Unequal regrowth of hair occasionally seen after treatment. The areas where hair is growing slowly were previously occupied by the disease. The end-result was perfect. Compare with Fig. 107.

Possible Dangers.—The possible dangers associated with the x-ray treatment of tinea tonsurans consist of first, permanent alopecia and second, injury to the brain.

MacLeod disposed of the second item as long ago as 1909. In Dr. Fordyce's clinic over 1200 patients have received the treatment in the last ten years. In France and England many thousand cases have been so treated. Yet there is not a single record in the literature of injury to the brain—either immediate or remote. This is true for children of any age, even infants, and with any quality of radiation, with the understanding of course, that the dose is limited to that required for epilation.

Ten or fifteen years ago permanent alopecia following irradiation for tinea tonsurans occurred rather frequently. In the past ten years it

is doubtful if this unfortunate result has occurred in more than two or three in a thousand. Most of the experienced operators have had no such cases in the past eight or ten years. The author had one case of permanent alopecia in 1912, the result being due to a technical error made at a time when technic was comparatively very unreliable. Since 1912 not a single case of permanent baldness has occurred in the author's laboratories in spite of the fact that the technical work has been done by a number of physicians, technicians and students, always of course, under proper supervision. As far as can be ascertained by experience and a knowledge of the literature, there is no danger of permanent alopecia without an antecedent radiodermatitis of at least the first degree. There is no danger of such radiodermatitis on the scalp unless the dose has exceeded H1¼ S. D. (in children under two years of age, H1 S. D.) or unless there has been an error of judgment such as using irritating chemicals, repeating the *x*-ray treatment too soon in case of relapse, etc. There is always the question of true idiosyncrasy but, fortunately, this unpleasant possibility is very rare.

FIG. 106.—Atrophy, telangiectasia and permanent alopecia due to excessive *x*- ray dosage.

Fig. 106 shows the result of excessive dosage, namely, permanent alopecia, telangiectasia and atrophy.

Williams studied the hair after the administration of intensive and fractional doses of *x*-rays. He found no nutritional changes in the hair after a single epilating dose. When repeated small doses had been applied to the scalp, nutritive alteration of the hair was quite marked. In this connection Adamson noted ringed hairs (alternate light and

dark areas due to irregular air content) among the depilated hairs following a single epilating dose. It can be said with certainty, after fifteen years' experience with the *x*-ray treatment of ringworm of the scalp, that barring excessive dosage, there is no deleterious effect on the hair.

Subsequent Treatment.—The *x*-rays cause depilation; they have no direct effect on the fungus. The fungi inhabit the hairs and when the hair falls the organisms are removed from the follicles. If any organisms remain on the scalp or in the follicles after the hair begins to regrow the disease again becomes active. Furthermore, fungi are likely to be in the house, in the clothing, on domestic pets and animals or on other children, so that when the hair begins to grow reinfection may occur. To avoid relapse and reinfection it is advisable to apply antiparasitic treatment to the scalp.

Between the time of the treatment and the defluvium and during the latter, the scalp should be washed daily with soap and water. If there is considerable inflammation in the diseased areas a wet dressing of aluminium acetate or boracic acid is indicated. After the defluvium the scalp may be bathed daily with a 1 to 5000 solution of corrosive sublimate in 50 per cent. alcohol. One week after the defluvium it is permissible to apply daily a 5 per cent. ointment of ammoniated mercury or precipitated sulphur. Two weeks later the strength of these applications may be increased. Irritating chemicals should not be employed for the first few weeks after the treatment and, later, when they are used the scalp should be watched for signs of inflammation. At the slightest sign of reaction soothing applications must be at once substituted.

The non-infected children of the same family should receive local chemical applications as a prophylactic measure.

When the hair begins to fall it is a good plan for the mother or the nurse to apply pieces of zinc plaster to the scalp. After a few minutes these are removed with the loose hair attached. They are then burned. The procedure is repeated once or twice daily in order to avoid spreading the causative organisms about the house. In addition it is well to have the child wear a linen skull cap—one that can be boiled. These details are especially important when there are uninfected children in the same building.

Criterion of Cure.—After the hair begins to regrow the scalp is watched for broken hairs and scaly patches. The scales and hairs are then examined microscopically. If spores are not found within a month the patient may be declared cured with the admonition that the scalp must be kept clean and sulphur ointment used for several months to avoid reinfection.

A mild pityriasis capitis is often noted after irradiation for tinea tonsurans. In the absence of spores this scaliness should be treated as seborrhea capitis and not as ringworm.

Relapses.—If proper precautions are taken relapses will not occur in more than ½ per cent. Reinfection occurs a little more frequently. Reinfection and relapses combined, even among out-patients, is not greater than 5 per cent.

Treatment of Reinfection.—The question arises, how soon after treatment can a scalp be again irradiated in case the first treatment failed to effect a defluvium or in case of relapse or reinfection?

In the first case the answer is six weeks. In case of reinfection or recurrence the scalp may be again irradiated as soon as the hair is growing vigorously. This will vary from three to six months or even longer.

FIG. 107.—Regrowth of hair two months after universal depilation with *x*-rays. In this instance the areas in which the growth of hair is most vigorous were formerly occupied by the disease.

The author has had numerous cases where a single small area was depilated and later the entire scalp became infected, necessitating a universal defluvium. As soon as the hair began to grow vigorously in the treated area the entire scalp was irradiated. In not a single instance was there a permanent alopecia as a result of the double exposure and not infrequently the hair began to grow sooner and grew more rapidly in the original patch than upon the rest of the head (Fig. 107).

Advisability of Depilating Entire Scalp.—Many ringworm patients when first seen by the operator, present only one or a few small areas of disease. In such instances, providing the parents have the intelligence, time and interest necessary to carry out the physician's instruc-

tions, it is possible to effect a cure by confining the treatment to the affected areas. As a rule, especially in dispensary work, such treatment is followed by a dissemination of the disease throughout the entire scalp. The reasons for this are:

1. At the time of the treatment all visible areas of disease are exposed. But there are likely to be infections in other parts of the scalp which have not become manifest at the time of the treatment.
2. Infection of other parts of the scalp may occur after the treatment in spite of intelligent prophylactic measures. The fungi may be transferred from old to near areas by the fingers or by the cap or hat. The fungi might be scattered around the house or on domestic animals or pets.
3. Dissemination of the affection is likely to occur at the time of the defluvium.

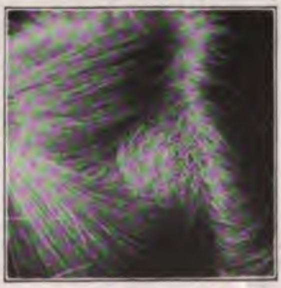

FIG. 108.—A small patch of ringworm.

FIG. 109.—*X*-ray depilation of hair in and around the patch of ringworm shown in Fig. 108.

Fig. 108 shows a scalp with a silver-dollar-sized area of ringworm. A palm-sized area, including the lesion, was depilated (Fig. 109). Shortly after the defluvium the disease spread over the entire scalp as shown in Fig. 110. In this picture one might think that the scalp had been depilated by means of the *x*-rays. Such, however, is not the case. Every hair on the head was broken off close to the scalp as a result of the disease. Fig. 101 shows the same head after depilation by the five-exposure method. Subsequently the hair regrew luxuriantly and there was no further trouble. Fig. 111 represents a child who had several dime-sized areas of ringworm in a circumscribed area. A single area was depilated as shown in the picture. The remainder of the scalp remained normal and the hair regrew in the irradiated area in the usual time.

Hazen records a private patient whose mother refused to have the whole scalp depilated. Thirty-four different treatments were given to various-sized patches before final recovery took place. Most operators have had this same experience.

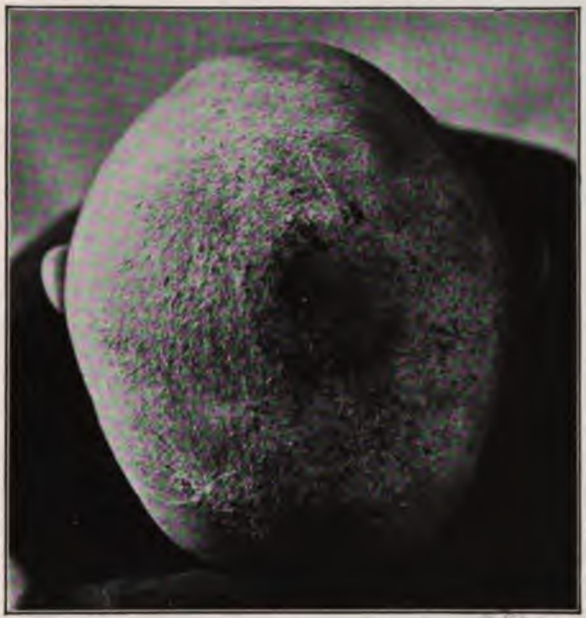

FIG. 110.—Same patient shown in Figs. 108 and 109. When the hair fell out it spread over and infected the rest of the scalp. The disease has caused a breaking off of all the hair close to the scalp. This picture was taken before the five-exposure method was used. The patient was later treated by this method with a perfect result.

FIG. 111.—Numerous small patches of ringworm confined to one area. In this instance one area of a size sufficient to cover all the disease was treated. The result was perfect.

For various reasons it is preferable at times to limit the treatment to one or more circumscribed areas. In such instances, in order to avoid dissemination of the affection, it is advisable to wash the head daily with soap and water and to apply a 1 to 5000 solution of corrosive sublimate in 50 per cent. alcohol to the entire scalp with the exception of the irradiated area. The treated area should be covered with zinc plaster which is not to be removed until the third week, at which time the depilated hair will come away with the plaster and may be burned. New areas of disease that develop in the meantime must, of course, be irradiated. It is advisable, also, to destroy old hats and caps and to search for the original source of infection.

In institutions and dispensaries it is usual and advisable to depilate the entire scalp even in instances where only one small area of disease is demonstrable.

FIG. 112.—Atrophy and some permanent alopecia caused partly by *x*-rays and partly by the kerion type of ringworm.

Permanent Injuries Not Caused by X-rays.—The *x*-rays are sometim blamed for undesirable results that are partly, often entirely, due the disease. In Fig. 112 is shown a boy who had multiple keri (suppurative ringworm). The permanent alopecia here is partly to the destruction of the hair follicles by the disease and partly by *x*-rays which were administered in a dispensary by the fracti method many years ago. Areas of permanent alopecia have noted, also, in small-spored ringworm.

Treatment of Kerion.—Tinea tonsurans consists usually of circu scribed, few to numerous, areas of scaliness and broken hairs. Th affection may be localized, generalized over the scalp or even universally distributed over the scalp. Occasionally one meets with a pus-produc

ing type. Here there is one or there may be numerous boggy swellings known as kerions. Rarely this type of ringworm may invade the entire scalp and give rise to considerable pain, fever, and rather serious toxic symptoms. In mild examples of kerion the affection may undergo a spontaneous cure through destruction of the hair follicles by suppuration. Because of the danger of dissemination it is preferable to irradiate these cases at once. If thought advisable a single area may be treated but in most instances it is preferable to depilate the entire scalp.

Several years ago the author saw a patient who demonstrated the possible seriousness of this affection. The patient was a boy, eight years of age, who contracted the suppurative type of ringworm from a domestic farm animal. The affection became disseminated over the scalp. The scalp was almost a solid mass of kerions and there was considerable pus between the scalp and the skull. The boy was suffering from pain, lack of sleep and he was emaciated and toxic. The scalp was irradiated by the five-area method but the patient almost died before the hair fell out. After the defluvium recovery was rapid and uneventful. Much to the surprise of those interested there was, subsequently, a good head of hair. The author has had a number of similar but less severe cases and as a rule the hair returns in the areas formerly affected. At times, however, the suppurative type of the disease produces scarring and more or less permanent alopecia. Fig. 113 shows a case of multiple kerion after depilation.

FIG. 113.—Kerion type of ringworm after depilation.

Fractional Versus Intensive Treatment.—If one desires to do so it is possible to obtain a defluvium by means of fractional doses. $H\frac{1}{4}$ S. D. applied every five days for four doses, or $H\frac{1}{3}$ S. D. weekly for three doses, will usually suffice for the desired result. Occasionally it is

necessary to slightly increase the size of these doses. If defluvium does not follow this routine it may be repeated in a month with larger amounts. The hair usually begins to fall out about a week after the last treatment.

Radium.—The author has not heard of radium being employed in the treatment of tinea tonsurans. Its successful use over the entire convex surface of the head would require a special technic with a specially constructed applicator containing a large amount of emanation. Small, isolated areas might well be treated with flat or flexible applicators. The "soft" and "medium" beta rays should be eliminated by means of suitable screening.

FIG. 114.—Favus of the scalp, showing thick crusts that must be removed before roentgenization.

FAVUS.

Favus of the glabrous skin is so readily cured by dermatological remedies that the *x*-rays are not indicated. In fact their efficacy in such lesions is not known.

Favus of the scalp is a much more stubborn and serious disease than is tinea tonsurans. Unlike the latter it attacks individuals of any age. When occurring in children it does not undergo spontaneous involution at the age of puberty. It destroys the hair follicles and, unless cured, will effect atrophy of the scalp and permanent baldness.

It is the consensus of opinion among dermatologists that the *x*-rays offer practically the only satisfactory method of combating this disease when it attacks the scalp. Radium has not yet been used for this purpose.

The technic of application is exactly the same as that outlined for

the treatment of ringworm of the scalp. There are, however, a few special features to be considered. In favus the scalp is likely to be

Fig. 115.—Disseminated favus of the scalp before treatment. Note atrophy and permanent loss of hair due to the disease. Note also the so-called favus cups.

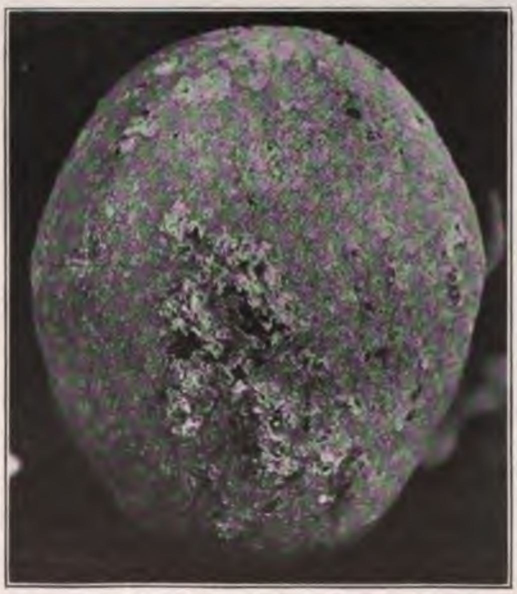

Fig. 116.—Same as Fig. 115, after the Adamson five-exposure method.

covered with thick and rather adherent crusts (Fig. 114). These crusts, unless removed, will by absorption of radiation, prevent epilation. It is not safe to increase the dose because some parts of the scalp may not be crusted. The usual procedure is to use a soap poultice for two or three days after which the crusts can be easily removed.

Subsequent to the treatment it is very important to wash the scalp daily and as soon as defluvium occurs daily applications of a 1 to 5000 solution of corrosive sublimate should be made. The antiparasitic ointments (5 to 10 per cent. ointments of ammoniated mercury, or precipitated sulphur or iodine) should be begun from four to six weeks after the treatment and continued (in the absence of inflammation) for several months.

FIG. 117.—Permanent alopecia and atrophy due to favus.

The dose required for epilation in cases of favus is likely to be a little larger than for tinea tonsurans. This may be due in part to the fact that the patients are as a rule older. But, also, the favus scalp appears to be less sensitive to the *x*-rays. It is the rule to give H1¼ S. D. for the first treatment. If this fails to depilate, a second application consisting of H1½ S. D. is administered one month after the first treatment. The author had one patient who required a dose consisting of H1¾ S. D. Figs. 115 and 116 show a favus scalp before and after the defluvium occasioned by the Kienböck-Adamson five-exposure method. In this instance the dose for each area was H1¼ S. D.

In spite of every precaution the percentage of recurrences is likely

to be high. Sometimes it is necessary to depilate two or three times in the course of nine months before a permanent cure is effected.

Before treatment the physician should explain the nature of the disease to the patient or the patient's family. Otherwise the physician may be unjustly blamed for the possible atrophy and permanent baldness occasioned by the disease. Fig. 117 shows a case of favus that has been cured by means of the x-rays. The entire scalp was depilated. The atrophy and baldness are due to the disease and were present before the x-ray treatment was given.

To avoid the sequelæ of the disease it is necessary to make an early diagnosis and to apply x-ray treatment before permanent injury to the scalp has occurred.

TINEA BARBÆ.

(RINGWORM OF THE BEARD.)

The x-rays form a convenient and certain treatment for the relief of tinea barbæ. Some dermatologists consider it to be the best form of treatment for this affection. As a rule the lesions are isolated and not numerous. At times a number of the boggy lesions constitute a palm-sized area of disease. Occasionally the lesions are scattered over the entire bearded region.

Technic.—The technic of application will depend upon the extent of the affected surface. If there are one or a few scattered lesions it will suffice to irradiate the individual lesions. A cluster of lesions may be treated in the same manner. At times it is necessary to irradiate one side of the face and neck and even the entire bearded region. The parts of the face and neck occupied by the beard constitute an exceedingly irregular surface and yet it is necessary to apply an equal amount of radiation to the entire affected region. This may be done by dividing the bearded region into a number of small areas by means of a skin pencil. Each area is then irradiated in succession, care being taken not to expose the same area twice and to avoid overlapping of the treatments. For many reasons this is an unsatisfactory and obsolete method.

Kienböck's Method.—Four exposures are necessary:

1. Anode placed directly over the center of the upper lip.
2. Anode placed directly over the angle of the right mandible.
3. Anode placed directly over the angle of the left mandible.
4. Anode placed over the center of the chin in such manner that an imaginary line from the target to the center of the chin will be almost but not quite at right angles with a similar line running from the center of the upper lip to the target with the tube placed in the first position (Fig. 118). To obtain this position it is necessary to have a specially constructed head-rest or to place a sand-bag or a block of wood under the back of the neck with the patient lying on his back. A folded pillow will not answer the purpose because it may allow change of

position during the exposure. As shown in the figure the head must be thrown well back.

Distance.—The distance may be anything over 6½ inches. A shorter distance does not permit the proper spreading of the radiation. A distance of 8 inches is recommended. It is very important that the target-skin distance be the same for each exposure. It is equally important that the head remain steady during the exposures.

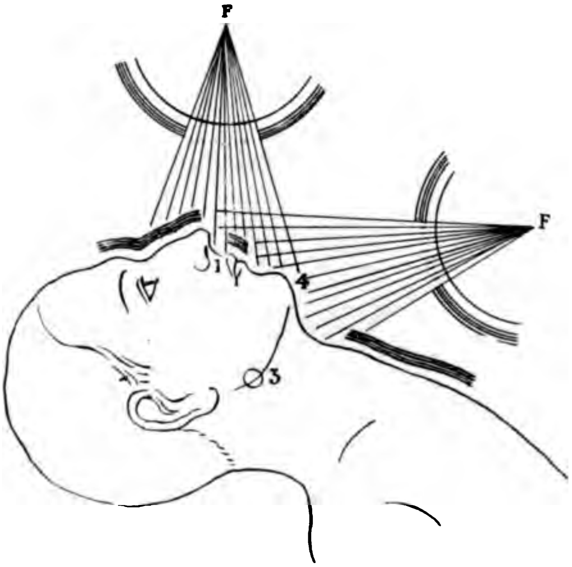

Fig. 118.—Showing the angles of incidence for treatment of sycosis and hypertrichosis of the face. (Kienböck.)

Dose.—Unfortunately the question of dosage is not as simple as when treating the scalp. On the scalp an epilating dose will effect a defluvium without provoking an erythema. On the face an epilating dose (H1 S. D.) is very likely to cause a first-degree reaction and even a mild first-degree reaction may be followed several months later by telangiectasia. Furthermore, in many instances, it requires a larger amount of radiation to depilate the beard than it does to depilate scalp hair. The author is not in favor of applying a full epilating dose at one sitting in the treatment of tinea barbæ. One can try H¾ S. D. and the result may be a defluvium. Experience has shown that with properly spaced fractional doses it is possible to depilate the beard without effecting an erythematous reaction. Such treatment consists of H¼ S. D. every five days for from four to six treatments or H⅓ S. D. every seven days for three or four treatments. In cases where the hair has not fallen out as a result of a total dose of H1¼ S. D. or H1½ S. D. and there is no evidence of erythema, one may proceed cautiously at the same rate until the total amounts to H2 S. D.

Protection.—The entire head, above the bearded region, is to be protected with lead foil or other suitable material. The same is true of the chest and shoulders and the unaffected portions of the anterior and lateral surfaces of the neck. The mucous surfaces of the lips should be carefully protected. This is important. If the hairy portion of the upper lip is not involved, it too should be covered with protecting material.

The four-exposure method does not provide an absolute equalization of dosage for such an irregular surface but it answers practical requirements. It is obvious that equalization of quantity is occasioned by the overlapping of the oblique rays from the four exposures in accordance with the law: intensity varies inversely as the square of the distance or directly as the sine of the angle.

Additional Treatment.—Care must be taken not to allow the use of irritating lotions or ointments, immediately before, during or immediately after the treatment. The parts may be bathed daily with soap and water and shaving is permissible. If the entire bearded region has been irradiated, mild antiparasitic salves (3 to 5 per cent. ammoniated mercury or precipitated sulphur) may be applied a week or two after the defluvium providing they do not provoke inflammation. If isolated areas have been treated the rest of the bearded region should receive antiparasitic treatment, care being taken to avoid the irradiated parts.

When defluvium occurs the result is a cure. Reinfections and relapses are not common. If the epilating dose is administered at one sitting the hair falls out in two or three weeks. When the treatment is administered fractionally, defluvium usually occurs four or five weeks subsequent to the first exposure. The quality of radiation is of no importance excepting that it is possible that with filtered rays there is a little more latitude between the amount necessary for depilation and the amount that will provoke an erythema. The epilating dose for filtered radiation is from H1½ S. D. to H2 S. D. The latter dose is very likely to effect a mild first-degree reaction on the skin of the face and anterior neck.

Radium.—The author is not aware of attempts to treat this disease with radium. Isolated lesions should respond well to such treatment if properly applied. The treatment of the entire bearded region with radium can be done but with less facility than with *x*-rays. If radium is employed one should screen the applicator so as to utilize the gamma or the more penetrating of the beta rays. If "soft" and "medium" beta rays are employed erythema without defluvium is likely to result. For the same reasons as given for *x*-rays, fractional treatment is preferable.

ONYCHOMYCOSIS.

(FAVUS AND RINGWORM OF THE NAILS).

Roentgenization is of somewhat uncertain value in this exceedingly recalcitrant affection. The difficulty of ascertaining its real value is

largely a matter of diagnosis. Cultural or at least microscopical verification is usually necessary to support a clinical diagnosis and it is unwise to record statistics relative to the treatment of onychomycosis without such confirmation.

There is not the slightest question regarding the efficacy of the *x*-rays in some cases of onychomycosis. The author has a record of 96 cases of onychomycosis that have been roentgenized. In 30 cases the diagnosis was verified by microscopical examination. Of these, 10 cases made a prompt recovery, 8 cases recovered after prolonged treatment (18 cures) and 12 cases failed to improve.

In a few instances the rapidity of cure was astonishing as not more than six or eight fractional applications were administered. Wise, in a verbal communication, tells of 3 similar cases. In other instances as many as ten intensive treatments were given before the desired result was obtained.

The author is not prepared to state which is the better treatment—intensive or fractional—insofar as concerns efficacy. Other forms of treatment are so difficult of administration and so disappointing in results, that it seems permissible to say that while all cases will not respond favorably to roentgenization yet such treatment is the method of election and, if possible, should be given a trial.

Technic.—Before applying the *x*-rays the nails should be prepared for the treatment. They should be soaked for an hour or two in hot soapsuds, then scraped with a knife.

If there is no paronychia only the nail should be irradiated. If there is paronychia it is necessary to expose the skin for one quarter of an inch around the nail.

It is not wise to evoke an erythema of the skin around the nail, therefore fractional, semi-intensive or subintensive doses are indicated. If the nail is thick and it is not necessary to irradiate the surrounding skin, intensive and even hyperintensive doses may be administered. The nail will absorb a considerable quantity of this radiation.

Because of the difference in toleration between the nail and the skin it is a good idea to apply a larger dose to the former than to the surrounding parts. Because the affection is under the skin (paronychia) and in and under the nail (onychia) filtration may be of advantage.

The affection often involves several nails. It is possible to so arrange the hands that from two to six nails can be treated with one exposure. By closing the hands and placing the knuckles together the thumb nails are approximated. The nails of the index, middle and ring fingers of both hands can be placed on the operating table in such manner that they will fall well within the field of radiation and, therefore, may be exposed at one time. With the exception of the nails of the great toes, which are approximated and treated simultaneously it is customary to irradiate each toe nail separately.

It is not known how the *x*-rays effect a cure in ringworm of the nail. There is no sudden defluvium after an intensive treatment followed by

a period of quiescence and then regeneration as is seen in temporary alopecia, but, nevertheless there may be an analogy. The author has seen the shedding of a nail after an intensive treatment, but the process is very slow, the old nail being gradually expelled as the new one grows.

FIG. 119.—Ringworm of the nails before roentgenization.

FIG. 120.—Same as Fig. 119, after four intensive treatments.

It is possible, therefore, that the efficacy of the x-rays lies in their ability to temporarily arrest development which is followed by the shedding of the old nail as the new one develops and that this phenomenon is so gradual that it is usually overlooked. On the other hand,

cases have been observed where the disease disappeared, apparently as a result of roentgen therapy, and there was, at no time, any noticeable arrest of growth. In these instances the older and diseased portion of the nail was gradually cut away and the newer growth remained healthy.

Antiparasitic remedies should not be employed two weeks previously, during, nor for two weeks subsequent to roentgen treatment, unless of very mild strength such as a solution of corrosive sublimate 1 to 5000 or a 3 per cent. ointment of ammoniated mercury or precipitated sulphur. The author dispenses with these remedies entirely and depends upon soap and water for cleanliness and prophylaxis. Relapses are not common.

Figs. 119 and 120 show a case of onychomycosis before and after roentgen treatment. The clinical appearance is more suggestive of dystrophy but spores were found in the scrapings, and cultures were obtained from scrapings from the nail of the index finger of the right hand. These spores resembled, morphologically and culturally, those of ringworm. There were no lesions of psoriasis or eczema on the body. The duration was one year.

Radium.—The author has not employed radium in the treatment of onychomycosis nor has he seen reference to such treatment in the literature. Radium rays will certainly be fully as efficacious as will the *x*-rays if properly applied. On account of the convexity of the nails a flat applicator is not suitable unless placed at a considerable distance. It would seem preferable to use a flexible applicator composed of tubes containing emanation or radium salts, such applicator being placed at a distance of several centimeters.

RINGWORM OF THE GLABROUS SKIN.

Roentgen therapy is of no value in ordinary ringworm of the glabrous skin—tinea cruris, tinea circinata, etc. When ringworm fungi produce lesions of eczematous type, irradiation may be of considerable service. Eczematoid ringworm, eczema marginatum, etc., will be found in the chapter on eczema.

ACTINOMYCOSIS.

Actinomycosis is a rare disease and not many examples of the affection have been treated with the *x*-rays. From personal observation and a review of the literature, the author is of the opinion that the roentgen rays or radium rays are not only indicated in this stubborn and serious disease but that such treatment is superior to any other. Unfortunately most of the reports found in the literature state that both potassium iodide and *x*-rays were used and while the opinion prevails that the involution of the ulcers, sinuses and nodules was due to the *x*-rays, yet the fact that potassium iodide was administered makes the cause of the recovery a little uncertain. The fact, however,

few cases of actinomycosis have been cured with x-rays (or alone shows that such treatment is efficacious.

21.—Actinomycosis before x-ray treatment. (Patient referred by Dr. F. Steinke.)

—Same patient shown in Fig. 121, after two subintensive x-ray treatments. (Patient referred by Dr. F. Steinke.)

by successfully treated 3 cases of actinomycosis with a com-
of iodide of potash internally and x-rays locally. Bevan

makes a similar report. Harris cured a severe case of actinomycosis of the neck by the combined treatment. These authors are convinced that the *x*-rays cause the involution of the cutaneous lesions.

Zeisler failed to cure a case with iodide of potash. The lesions disappeared apparently under the influence of the *x*-rays but the patient also took copper sulphate internally. Heyerdahl reports the cure of 3 cases each of which received but one radium application. A fourth patient died.

Figs. 121 and 122 show a patient with actinomycosis, before and after roentgen treatment. The patient was referred to the author by Dr. F. Steinke, of Elizabeth, N. J. One intensive dose of *x*-rays was administered. Improvement began in two weeks and the eruption disappeared in a month. A second intensive dose was given at this time as a prophylactic. There was no local recurrence and no extension of the disease to other parts. The patient received no treatment other than the *x*-rays. The clinical diagnosis was confirmed by microscopic examination.

Pels reports a case of actinomycosis of the hand that was clinically cured after receiving three intensive *x*-ray treatments, the radiation being filtered through ½ mm. of aluminium. The patient, however, also received iodide of potash internally.

With such limited experience very little can be said relative to technic. The author's case was cured by intensive treatment as also were those treated by Pels (*x*-rays) and Heyerdahl (radium). The others were treated with very small repeated applications (exact dosage unknown). Inasmuch as the lesions are deep-seated, filtered radiation might have given even better results. All the cases so far treated with *x*-rays, with the exception of the one reported by Pels, have received unfiltered radiation. Filtration is, of course, necessary when radium is used, as only the "hard" beta rays or the gamma rays should be utilized.

It will be interesting to ascertain the effect of heavily filtered *x*-rays or gamma rays on the lesions of systemic actinomycosis.

BLASTOMYCOSIS.

What has been said under actinomycosis answers pretty well for blastomycosis. It is not quite so rare so that there are a larger number of recorded cases treated with *x*-rays. So far only the cutaneous lesions have been treated. It would be very interesting to learn the effect of irradiation on the visceral lesions.

Pusey, Gilchrist, Ormsby, Fischkin, Zeisler and others have cured cases of cutaneous blastomycosis with a combination of potassium iodide and *x*-rays. Ormsby completed several cures with the *x*-rays. Montgomery, Oulmann, Knowles, and Pusey record cases where there was great improvement following the use of *x*-rays without any other

treatment. The patients were presented at society meetings and recorded before the cure was completed.

Davis presented a patient afflicted with blastomycosis before the Philadelphia Dermatological Society. Iodide of potash proved useless in this case. The lesions, when the patient was presented, had almost disappeared as a result of roentgenization. Montgomery records a case of cutaneous and systemic blastomycosis. The cutaneous lesions disappeared under *x*-ray treatment but they recurred and the patient died. Winfield presented an interesting case of blastomycosis before the New York Dermatological Society. Iodide of potassium had proved useless. The eruption disappeared entirely under the influence of the *x*-rays. Ravogli found *x*-rays more useful than iodide of potash. Simpson records a complete cure of a case of cutaneous blastomycosis with radium.

The author has cured several cases of localized cutaneous blastomycosis with both fractional and intensive doses of *x*-rays. There was a relapse in only one case. In most of the cases the lesions disappeared as a result of one or two intensive treatments or from six to twelve fractional applications. In one instance, a farmer with a lesion occupying the entire dorsal surface of one hand, the treatment was apparently ineffectual. After receiving two intensive treatments the patient returned home discouraged. A letter was received from him in three weeks stating that the lesion had disappeared shortly after returning home. No other treatment had been given.

All the cases so far treated with *x*-rays have been given unfiltered radiation. As a rule cutaneous blastomycosis is not as deep-seated as are the lesions of actinomycosis. It is questionable if a filter would add to the value of the treatment unless the lesions are unusually deep-seated or when the viscera are involved.

It is possible that *x*-rays and radium may be found of service in sporotrichosis, amebiasis cutis, dermatitis coccidiodes and nocardiosis cutis. In these affections, however, internal treatment is usually quickly efficacious. J. B. Shelmire, of Dallas, and E. D. Crutchfield, of Galveston, have successfully treated sporotrichosis with *x*-rays without the use of iodide of potash or other remedies (verbal communication).

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CHAPTER XXII.

ECZEMA.[1]

The conditions discussed in this chapter are:

1. Dermatitis Venenata.
2. Eczematoid Ringworm.
3. Eczema Marginatum.
4. Neurodermatitis and Lichenification.
5. Infantile Eczema.
6. Dermatitis Seborrheica.
7. Intertrigo.
8. Regional Eczema.
9. Eruptive Types of Eczema.

The *x*-rays have been used successfully in the treatment of eczema almost from the very beginning of roentgen therapy. Ullmann recommended such treatment for chronic eczema as far back as 1900. Jutassy, Schiff and Freund, Hahn, Sjogren and Sederholm, Albers-Schönberg, Mackey, Scholtz, and others, found that subacute and chronic eczematous lesions disappeared as a rule with great rapidity as a result of a few mild *x*-ray treatments. Williams, Meek, Pusey, Allen, Hyde, Montgomery and Ormsby, Robinson, and Zeisler were the first to employ *x*-rays for this purpose in the United States. Pusey and Williams determined that irradiation was useful in acute as well as subacute and chronic eczema.

In the past twenty years it seems that almost every dermatologist and roentgenologist has written on this subject. Certainly the literature is voluminous, and for the most part the articles are only of historical interest. There are advocates of fractional treatment and advocates of intensive treatment. Many of the early workers did not hesitate to produce reactions. Very early the opinion was unanimous that in most instances the lesions of eczema disappeared with astonishing rapidity under the influence of very small doses and in practically all cases the itching was relieved at once. At first it was thought that the clinical cure might be permanent but later it was found that recurrences were common.

Modern writers are perhaps even more enthusiastic than were the earlier authors. The results are better today because of greater ability to select cases and because modern technic practically precludes injury. All modern text-books on dermatology and roentgen therapy call attention to the efficacy of irradiation in the treatment of eczema, especially the chronic types. Wise has found the *x*-rays especially valuable in the treatment of recurrent eczema of the hands. Blaschko,

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

It will suffice for our purpose to know that the eczema of our forefathers has been and continues to be split into separate entities, the splitting being due to a better interpretation of eruption characteristics and increased knowledge relative to etiology. It should be obvious from the foregoing and it will be more obvious from what follows, that much is left to the imagination when one states that eczema, acute or chronic, is benefited or cured by irradiation—we must be more specific; we must state as nearly as possible the type of eczema or dermatitis that is being treated.

DERMATITIS VENENATA.

Dermatitis venenata may be defined as a reaction of the skin to the local action of chemicals and drugs. The eruption may be acute, subacute, or chronic. The chronic type may develop insidiously or it may be preceded by acute or subacute symptoms. It is likely to be associated with frequent and very severe acute exacerbations. The behavior of the affection depends probably upon the nature of the causative agent, the frequency of contact, and the degree of susceptibility.

Dermatitis venenata may be caused by an exceedingly large number of substances all of which are mentioned in the various text-books on dermatology and especially in an article by Knowles on the external origin of eczema and in an excellent book by R. P. White. The most important of these substances are herwith appended:

Rhus and sumach, primrose, resinous woods, dyes (hair dye, dyes in fur, clothing, etc.), sulphur, mercury, chrysarobin, picric acid, pyrogallic acid, formalin and its products, strong soaps, metol, resorcin, iodoform, turpentine, varnish, lime.

And a great many more substances of animal, vegetable and chemical nature to which the individual has become sensitized.

The eruption caused by some of these substances is quite characteristic and may be recognized by the character of the elementary lesion, the sites of predilection, the course, the auto-inoculability, etc. Unfortunately this is true in only a relatively few cases, although an experienced dermatologist will usually find one or more characteristics that will lead to a correct diagnosis.

The *x*-rays are not indicated in the majority of cases of dermatitis venenata. If the case is properly diagnosed and the cause removed the eruption as a rule will disappear quickly; especially is this true of the acute types. At times, however, the diagnosis is exceedingly difficult; often quite impossible until after prolonged observation. Such cases have provided the author with material for study in connection with *x*-rays. Involution of acute eruptions and acute exacerbations is perhaps hastened and at time pruritus is lessened by fractional and subfractional irradiation. However, as good if not better results can be obtained by the proper choice and use of dermatological remedies.

In any event the detection and removal of the cause is the main requisite, otherwise the eruption is likely to persist or to recur repeatedly.

In former years the author irradiated a large number of recurrent eczematous eruptions often with apparent temporary success, only to find later that the exacerbations would disappear as quickly under the influence of dermatological remedies as with roentgenization. The eruptions continued more or less intermittently, however, until the cause was removed. A few of the most striking and illustrative cases are herwith briefly reported:

ILLUSTRATIVE CASE REPORTS.

CASE 7.—(*Match-box Dermatitis*).—A gentleman presented a very pruritic eruption on the anterior and lateral aspects of the left thigh, about half way between the hip and knee. The eruption consisted of a large patch (5 x 8 inches) of red, thickened and slightly scaly skin with a number of excoriations. The margin was not well marked. The duration was three years. The eruption improved considerably in winter but was always worse during hot weather. There had never been any acute symptoms. The diagnosis made at the time was lichenified eczema. Irradiation (fractional) at first caused cessation of itching and very great improvement in the appearance of the lesion. The *x*-rays soon ceased to have any effect, and the patch assumed again its original characteristics. It was about this time that G. H. Fox, Rasch and others reported cases of eczema (dermatitis) due apparently to the phosphorus contained on match-boxes carried in the pocket of the trousers. It was then ascertained that the patient was in the habit of carrying a match-box in the pocket of the left leg of his trousers. When this habit was discontinued the eruption disappeared and never returned.

A number of similar cases might be reported in which the dermatitis was on different parts of the thighs and buttocks, depending upon the location of the match-box, and in which irradiation was of very little value. The eruptions differ somewhat in type. Usually they are chronic but intermittent and there may be sharp exacerbations. It is the intermittent character of many types of dermatitis that may lead to the erroneous belief on the part of the roentgenologist or dermatologist that irradiation is of distinct service.

CASE 8—(*Toilet-seat Dermatitis*).—This name was given to a dermatitis occurring on the parts of the buttocks coming in contact with the toilet seat. Fred Wise first called attention to this variety of dermatitis and believes that it may be due to varnish, lacquer, substances from hard woods (volatile oils, etc.) or perhaps to decomposed urine or other secretions and excretions (Wise's observations are unpublished).

The patient was a male child four years of age. The eruption consisted of erythema, very slight infiltration, some scaliness and itching. The eruption had been present for two years. It improved at times but never disappeared. There were no acute outbreaks. Irradiation improved the condition considerably for a while but the eruption did not disappear until a porcelain toilet seat was provided.

CASE 9—(*Primrose Dermatitis*).—A lady exhibited a chronic, itchy, scaly eruption of the fingers; a chronic squamous eczema. The duration was six

years, during which time the eruption was always present, being worse at times and better at other times. She states that occasionally, at long intervals, there was an acute exacerbation consisting of edema, vesiculation and pain which lasted only a few days. At these times the eruption occurred in patches on the hands and forearms. No local cause could be discovered. Unfortunately, through a misunderstanding, the patient denied contact with the primrose plant. For six months irradiation and dermatological remedies were employed with some benefit. A very thorough and expensive investigation, for the purpose of discovering the supposed internal cause, was under way when an unusually violent exacerbation was seen by the author. The symptoms were identical with those seen in rhus dermatitis. Primrose plants were found in the patient's house and were destroyed. There has been no recurrence of the eruption.

The author has irradiated, without much real benefit, many cases of acute, subacute, and chronic eczema of the fingers, neck, ears, face and other parts of the body. Later, the eruption was found to be caused by resorcin in a hair tonic, hair dyes, fur dyes, leather hat bands, shoes, stockings, chemicals and substances used in the trades, etc.

SUMMARY.—Irradiation is of doubtful value in dermatitis venenata. It will perhaps hasten resolution of acute eruptions but will not prevent their occurrence. It will lessen the itching of chronic eruptions and may cause more or less involution, even their total disappearance. The relief, however, is temporary as a rule unless the cause of the affection is ascertained and removed. Removal of the cause is usually followed by permanent disappearance of the eruption. Occasionally, however, the eruption may persist for several months after the local cause has been removed, or the eruption may disappear only to return over and over again in spite of intelligent dermatological treatment. In such instances the eruptions will often disappear promptly when irradiated and not infrequently the result is a permanent cure.

Technic.—The author advises fractional or semi-intensive treatment —H¼ S. D. once weekly or H½ S. D. every two weeks. If there are only one or two lesions the normal skin should be protected. If the eruption is extensive the rays must, of course, be allowed to spread over the affected parts. Isolated areas of normal skin need not be protected as there is no danger from such small doses. If the disease does not disappear in from three to six weeks it is inadvisable to continue the treatment. Local applications containing such chemicals as tar, mercury, sulphur, salicylic acid, etc., are contra-indicated unless the *x*-ray dose is very small (H⅛ to H¼ S. D. once weekly).

INFECTIOUS ECZEMATOID DERMATITIS.

This affection, described by Engman and Mook, and by Fordyce (secondary eczema) may be defined as a dermatitis secondary to a discharging ulcer, sinus, boil, abscess, etc. The eruption may be dry but it is more likely to be exudative, crusted or pustular. It spreads by peripheral extension and by auto-inoculation. The affection is

supposedly caused by sensitization to bacterial products. It may complicate ecthyma, bed-sores, truss-sores, breast abscess, etc. Discharges from the nose, eyes, ears, anus, etc., may be the starting-point of the affection.

Results of Irradiation.—It is possible to obtain excellent results if the cases are properly selected and roentgenization is associated with intelligent dermatological treatment. The author has seen eruptions begin at the margin of an ulcer and later involve most if not all of the body surface. In cases of this kind, when the symptoms are acute—edema, erythema, exudation and burning pain—*x*-rays have been of little if any benefit until the affection has become subacute. If the eruption does not disappear after subsidence of the acute symptoms either spontaneously or as a result of dermatological treatment, roentgenization may be of distinct value.

In the less acute types, when the eruption is papular or squamous with or without more or less exudation, and severe itching, *x*-rays are, as a rule, more efficacious than any form of dermatological treatment.

Localized dermatitis, secondary to discharge from a cavity such as the ear, even when of the very acute type, will often yield quickly to irradiation.

To obtain a permanent cure it is of course essential that the type and cause of the dermatitis be recognized and steps taken to remove the latter.

Technic.—The technic will vary in accordance with the symptoms and the distribution of the eruption. Localized eruptions, even when acute, will often undergo complete involution subsequent to one or two semi-intensive treatments, or from two to four fractional applications. This statement is made with the understanding that it is possible to keep the exciting agent (discharge) from coming in contact with the inflamed skin. This may be often accomplished by the use of soothing, astringent and very slightly antiseptic wet dressings. Ointments and pastes are not advisable for this purpose because the discharge, if copious, will spread under the grease and reach the surrounding skin.

Widespread eruptions must be cautiously irradiated. These patients are already somewhat toxic and their skin is very sensitive. It is advisable, therefore, to employ very small doses (subfractional, increasing to fractional) and to expose only one small part of the body daily. Complete technical details for such treatment will be found in Chapter XIX under the heading of generalized roentgenization.

ECZEMATIZED RINGWORM.

The term eczematized ringworm can include any eruption of eczematous appearance that is caused by ringworm fungi. Hence is included in this group: eczema intertrigo of the toes and fingers (now included under eczematoid ringworm of the extremities), eczema marginatum,

eczematized ringworm of the body and eczematous eruptions of the pubic region, umbilicus, axillæ and under pendulous breasts when due to fungi, usually the epidermophyton inguinale (Sabouraud).

The member of this group that is of particular interest is the affection (eczematoid ringworm of the extremities) described by Djelaleddin Mouktar in 1892, by Whitfield and Sabouraud in 1910 and by Ormsby and Mitchell in 1916. The affection is limited to the hands and feet and occurs in three clinical varieties: (1) Acute vesicular or vesicopustular, clinically identical with acute vesicular eczema and pompholyx. It attacks mostly the fingers, toes, palms, and soles. (2) Chronic intertriginous, commonly seen between the toes, occasionally between the fingers. (3) Hyperkeratotic, clinically identical with chronic squamous eczema and occurring mostly on the soles, also on the palms.

First Type.—As a rule the best treatment for this type of eczematoid ringworm is some strong antiparasitic and antipruritic remedy such as Whitfield's ointment, tr. iodine, chrysarobin, and iocamfen. However, some cases do not do very well under this treatment and it is in such cases that irradiation is of great value. In many instances, especially eruptions on the hands, the lesions will disappear as a result of a single semi-intensive application or two or three fractional doses, combined with soothing local remedies such as Lassar's paste and calamine lotion, both of which may contain menthol, camphor and carbolic acid. Recurrence is common. Even stubborn or relapsing cases may at times be permanently cured with *x*-rays. It must be admitted that cases are numerous in which the eruption fails to disappear. One may combine irradiation with the strong remedies enumerated supra; if so the dose must be small—fractional or subfractional.

Eczematoid ringworm of this type, when occurring on the feet, appears to be more recalcitrant than when on the hands. The author has seen examples of this affection resist intensive, semi-intensive and fractional doses administered over a period of three or four months. Conversely there have been cases that failed to get well under antiparasitic treatment that were permanently cured as a result of six or eight fractional *x*-ray treatments.

Because of the difficulty of diagnosis one hesitates to state the value of irradiation in this affection. It is possible that the cases that respond readily to irradiation are not caused by fungi. In most cases the diagnosis has been clinical. In the relatively few instances where the clinical diagnosis has been confirmed by microscopical examination the eruption has been stubborn.

Personal impression is that eczematoid ringworm is more recalcitrant to irradiation than are similar eruptions due to other causes. This opinion may have to be modified as a result of longer experience. For a number of years prior to the work of Whitfield, Sabouraud, and Ormsby and Mitchell, the author was perplexed by the stubbornne-

of some examples of acute vesicular eczema of the hands and feet. It is possible that these rebellious eruptions, omitting dermatitis venenata, are caused by fungi.

As a summary, about all that can be said at present is:

1. The acute symptoms usually quickly subside under semi-intensive or fractional treatment, especially when combined with local soothing and antipruritic remedies.

2. Occasionally the affection is permanently cured. Very often, after subsidence of the acute symptoms, no further improvement is noted. Recurrences are common.

3. It is the author's opinion that the majority of cases will do better under intelligent antiparasitic treatment than under irradiation. Finally, both methods may be cautiously combined in recalcitrant cases.

Second Type.—There is no doubt whatever in the author's mind that properly administered dermatological treatment is superior to irradiation in this type of eczematoid ringworm.

Third Type.—The author has had better results with antiparasitic remedies than with *x*-rays in the treatment of hyperkeratotic eczematoid ringworm. There is always the question of diagnosis. But eruptions of this type, diagnosed microscopically, have been recalcitrant to irradiation.

Technic.—Fractional or semi-intensive doses are advisable because:

1. Inflamed tissue is hypersensitive to *x*-rays.

2. The susceptibility is increased by the previous use of strong topical remedies.

3. It has been found that if the eruption will yield to *x*-rays it will respond to small doses.

If the eruption does not disappear as a result of such treatment over a period of a month or two, it is unlikely to be favorably influenced by further treatment.

Filtered radiation is not more efficacious than are unfiltered *x*-rays.

It is often necessary to irradiate the lateral surfaces of the fingers and toes. This may be accomplished (for the fingers) by placing the palms on the table with the fingers widely separated. The *x*-rays are administered to the dorsal surfaces of the fingers. The dorsal surfaces of the hands are then placed on the table and irradiated. Both hands can be treated at one time. The same procedure is carried out for the toes, excepting that the latter must be held apart by gauze plugs.

If there is a single patch or only two or three isolated areas, the normal skin should be protected. In the case of a widespread eruption or if there are numerous lesions, it is preferable to allow the rays to spread over the hands. Such small doses will not harm the normal skin between the lesions.

Radium.—Unfiltered and filtered flat applicators have been used in the treatment of small lesions. The results have been about the same as those obtained with *x*-rays.

ECZEMA MARGINATUM.

There is some confusion relative to the use of this term which was given to the affection by Hebra. It is synonymous with tinea cruris and epidermophytosis inguinalis. The eruption may be confined to the crural region or may involve the thighs, pubic region, perineal region, umbilicus, axillæ and breasts. The causative agent is the epidermophyton inguinale (Sabouraud). The affection may be dry, vesiculo-pustular or exudative. There may be considerable thickening of the skin.

At times irradiation will relieve and even cure this affection but it is the consensus of opinion that such remedies as iodine, Dreuw's ointment, Whitefield's ointment, etc., properly employed, will effect a more speedy and permanent cure.

Ringworm of various parts of the body, especially when of the so-called moist type, may produce lesions that are eczematous in appearance, but sharply marginated. The terms parasitic eczema, eczema marginatum and eczematized ringworm are often used by clinicians to designate such lesions. While *x*-rays and radium will often cure eruptions of this type, the remedies enumerated supra provide a more satisfactory method of treatment.

NEURODERMATITIS.

Neurodermatitis includes or will include here lichenification, lichenified eczema, eczema nuchæ and lichen simplex (Vidal). There seem to be two very distinct types of the affection—circumscribed and disseminated. The circumscribed variety occurs as dime to palm-sized areas. There may be one or two patches or numerous lesions scattered over the body. The sites of predilection are the nucha, the lateral surfaces of the neck and the flexures. Lesions may occur, however, on almost any part of the body.

The disseminated type favors the flexures and flexor surfaces, but it may be quite generalized and even almost universal. It often simulates seborrheic dermatitis. There is usually a family history of hay fever and asthma and the patients are often sensitized to various proteins.

The objective symptoms are lichenification, more or less acanthosis and parakeratosis, excoriation and at times exudation. The subjective symptom is itching which may be intensive and which often precedes the appearance of the eruption. Those who desire a scholarly discussion of this affection are referred to an able article from the pen of Fred Wise (Neurodermatoses and Pseudo-Lichens, *Jour. Cutan. Dis.*, 1919, xxxvii, pp. 590–798).

Effect of Irradiation.—Most authors agree that irradiation, either *x*-rays or radium, is very effective in the circumscribed types of neurodermatitis. The author has found this treatment so satisfacto

FIG. 123.—Circumscribed neurodermatitis before treatment.

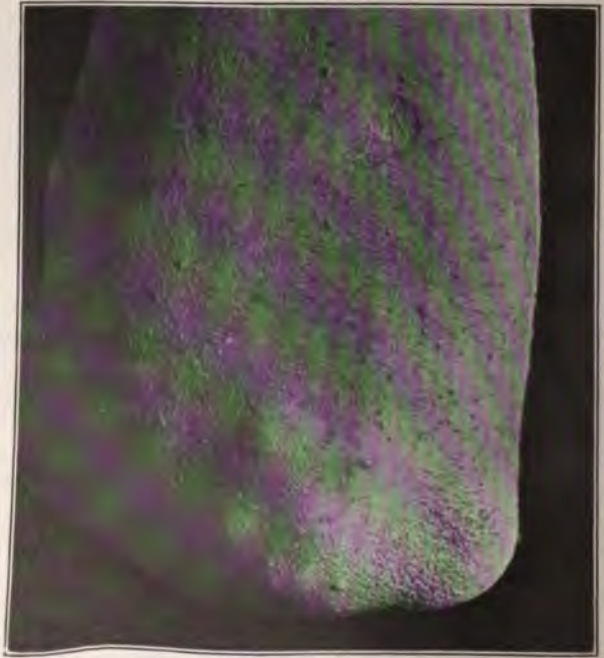

FIG. 124.—Same patient shown in Fig. 123, after six fractional treatments. S upper part of picture is the result of a biopsy.

so superior to any other treatment that he advises it as the method of election. This statement includes circumscribed neurodermatitis, lichen simplex, eczema nuchæ, primary and secondary lichenification, and similar conditions.

As a rule a few fractional doses or a single suberythema dose will suffice for a clinical cure. Occasionally the lesions are more stubborn and require treatment over a period of two or three months. Rarely an eruption will not improve or at least will not entirely disappear without an amount of radiation that is undesirable. It is preferable to avoid reactions and if the eruption does not disappear as a result of treatment over a period of two or three months, it is advisable to discontinue irradiation. Itching usually disappears before the eruption shows signs of involution. Recurrences are rather common, but they yield to another course of treatment.

There seems to be little if any difference in efficacy between the beta and gamma rays of radium, between radium and x-rays, or between filtered and unfiltered x-rays. When using radium, if there is much thickening of the skin, the "soft" beta rays should be eliminated by suitable screening. The author has noted little if any difference in efficacy between fractional, semi-intensive or subintensive treatment. Erythema doses produce more rapid involution but they are not justifiable. The normal skin around the lesions should be protected and strong topical applications are contra-indicated. It is permissible to employ diluted carbolic acid and menthol to allay the itching while awaiting the antipruritic action of the radiation.

Disseminated Neurodermatitis.—The effect of irradiation on this type of neurodermatitis is uncertain. The treatment practically always causes some relief, but it very frequently fails to cause complete disappearance of the eruption; especially is this true in children and convalescents. Even when the eruption does disappear recurrences are common. Nevertheless the x-rays are a valuable adjunct. The fact that they will lessen the itching and directly or indirectly improve the eruption in the majority of cases of this stubborn affection, is all that is necessary to justify their use. Furthermore, there is always the possibility of complete relief which may be even permanent. The author has obtained such results on several adults in instances where every other method of treatment failed.

Technic.—Inasmuch as it is often necessary to irradiate extensive surfaces, fractional or even subfractional doses are indicated. The reasons for this advice and the necessary technical details will be found in the chapter on General Therapeutic Considerations. With such small doses it is permissible to use stimulating local remedies. Everything possible should be done to ascertain and eliminate the causative factors.

INFANTILE ECZEMA.

Eczema of the face of infants may vary considerably in its clinical aspects. It may consist of scaliness with more or less erythema, it

FIG. 123.—Circumscribed neurodermatitis before treatment.

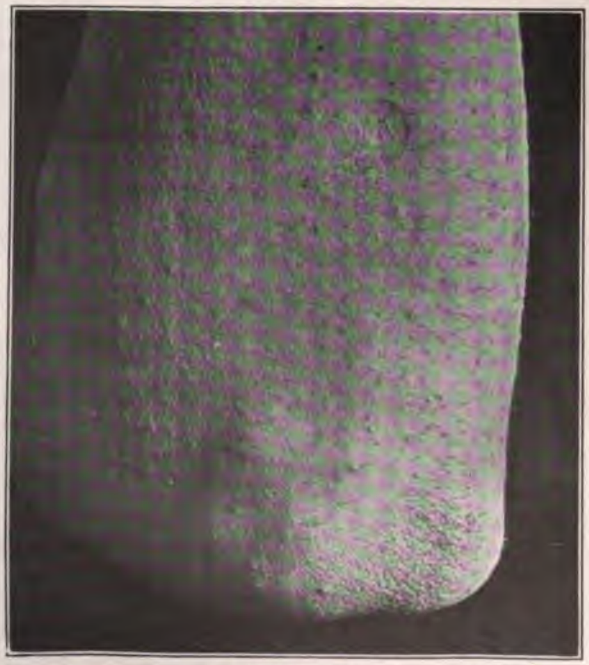

FIG. 124.—Same patient shown in Fig. 123, after six fractional treatments. Scar at upper part of picture is the res [illegible] psy.

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Eczema of the face of infants may vary considerably in its cl
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even after irradiation had been pushed to the point of visible atrophy. The nose tolerates long-continued treatment and larger doses better than do other parts of the face.

Scaly seborrhea of the face and body will at times disappear as a result of a few fractional treatments, but as a rule the affection can be more quickly cured with ordinary dermatological remedies. However, in stubborn cases, irradiation is at times of distinct value. These remarks may be applied, also, to the follicular type of the affection.

The best results may be expected in exudative eruptions and psoriasiform eruptions. While one meets with eruptions of these types that cannot be clinically cured with *x*-rays, the majority of cases will yield quickly and many of them permanently to irradiation. It must be admitted, however, that recurrence is rather common.

Because of the large number of lesions and the extent of the affected surface and, also the fact that these lesions are likely to be hypersensitive, fractional treatment is indicated. It has been the author's experience that if seborrheic dermatitis does not disappear as a result of from six to twelve fractional treatments at weekly intervals, it will not disappear as a result of further irradiation. (For details relative to the treatment of extensive surfaces see chapter on general therapeutic considerations.)

INTERTRIGO.

An inflammation of the skin situated in locations where there is moisture, warmth, friction and where it is difficult to keep the parts clean, is known as intertrigo. The usual sites are the crural region, the axillæ, the anal region, and the breasts (under pendulous breasts). The eruption usually consists of redness, maceration, erosion, exudation and itching or burning. It is necessary always to differentiate the affection from an eruption due to ringworm organisms. Eczema intertrigo or intertrigo eczema, is a term given to the eruption when the symptoms are more like those that were once called eczema—thickening, vesiculation, pustulation, etc.

As a rule intertrigo will disappear in a few days or a week or two under the influence of proper hygiene and the intelligent use of topical remedies. Occasionally, however, the affection persists in spite of such treatment. In such instances fractional irradiation is of distinct benefit. A few such applications will often suffice to effect a permanent cure. The most frequent location for persistent intertrigo, in the author's experience, is the skin under pendulous breasts; and it is here that irradiation has been of distinct service. The *x*-ray treatment should, of course, be combined with soothing local remedies, hygiene and, later, prophylactic measures should be instituted in order to prevent recurrence.

The method of applying *x*-rays to the crural region is discussed under the heading of pruritus; to the axillæ, under the heading of hyperidrosis.

To irradiate the gluteal fold the patient lies on his stomach and with

his hands the buttocks are separated. Or the buttocks may be separated by two pieces of wide adhesive plaster, the distal ends of which are attached to the table. To irradiate the skin under the breasts it is necessary for the patient to elevate the breasts with the hands. All unaffected parts should be shielded.

REGIONAL ECZEMA.

Eczema of the Scalp.—Both exudative and squamous eczema of the scalp may be greatly benefited by irradiation. In fact the *x*-rays are a blessing in some cases as they obviate the necessity of using disagreeable salves and lotions. The treatment may consist of $H\frac{1}{8}$ S. D. once or twice weekly until $H\frac{1}{2}$ has been administered. It is not safe to exceed this dose unless one does not mind a defluvium. Strong topical remedies are contra-indicated; slightly stimulating remedies are permissible. Crusts and exudates should be removed with oil or with water and mild soap before the *x*-rays are applied. If the entire scalp is affected the *x*-rays are administered in accordance with the Kienböck-Adamson five-exposure method (see psoriasis and tinea tonsurans). If more than one course of treatment is necessary a rest interval of at least three weeks between each course is advisable.

Eczema of the Face.—Exudative and squamous eczema of the bearded region will often disappear quickly and permanently as a result of a few fractional or subfractional treatments. The method of application is discussed under the heading of sycosis.

Eczema of the lips, nostrils, eyelids and ears will often disappear when treated either with *x*-rays or radium. For the eyelids the total dose in a month should be not more than $H\frac{1}{2}$ to $H\frac{3}{4}$ S. D. This is also true of the lips as the mucous membranes are rather sensitive. The eyes will not be injured by this amount of irradiation. However, it is not advisable to administer repeated courses of treatment to the eyelids. In treating obstinate cases, in order to avoid possible injury to the eye, it might be well to use "soft" beta rays of radium. However, the eyes are not very sensitive to the effects of irradiation and the author has not noted injury following the administration of large doses in the treatment of epithelioma of the eyelids.

Eczema of the Scrotum.—When irradiating the scrotum it is advisable to limit the total dosage to an amount that will not seriously injure the testicles. The testicles are extremely sensitive and prolonged treatment will effect azoöspermia. Six to eight fractional treatments will usually suffice to cure the eczema and this amount, in the author's experience, is not enough to do more than diminish, temporarily, the activity of the seminiferous tubules. It is not advisable to push the treatment beyond this point. When treating recalcitrant cases there will be less injury to the testicles with "soft" beta rays of radium than with gamma rays or *x*-rays. Chronic, lichenified eczema of the scrotum may require treatment directed at both the anterior and posterior

surfaces. A month or two of such treatment (x-rays) may seriou jeopardize the testicles. An unscreened flat radium applicator wo seem preferable in such instances. The "soft" beta rays act so quic that the amount of gamma and "hard" beta rays received by testicles would be almost negligible. Of course, there is a limit to s treatment but just what constitutes this limit the author does not kn

Fig. 125.—Acute vesicular eczema before treatment.

This question is discussed in greater detail under the heading of pruritus.

Eczema of the Nipple and Breast of Women.—Here the first requisite is to be certain that the case is not one of Paget's disease. If eczema of the nipple and breast (omitting the possibility of Paget's disease)

does not disappear as a result of one or two months' irradiation, it is inadvisable to continue the treatment for fear of injury to the underlying glands. In obstinate cases "soft" beta rays might be used to advantage.

Eczema of the Legs.—Ordinary eczema of the legs does not differ from that of other parts, but in this location there are special features to be considered. Here one meets with an eczematized skin associated with deep edema, the latter being due to varicose veins or cardio-vascular disturbances, and the former very largely to scratching. There may be more or less purpura. This type does not respond well to irradiation unless attention is paid to the underlying causative factors.

Fig. 126.—Same patient shown in Fig. 125, after three fractional doses of x-rays.

If this is done, *x*-rays will be of benefit by allaying the itching and promoting resolution of the thickened skin. They are of service, also, in hastening healing of exudative areas and ulcerations. Very often all the surfaces of the legs are involved necessitating multiple exposures (see chapter on General Therapeutic Considerations).

Eczema of the Hands and Feet.—Eczema of the hands and feet is often of the trichophyton or dermatitis venenata variety. These have been discussed in this chapter. Wise has found the *x*-rays of special service in recurrent patches of vesicular, vesiculo-squamous, and pustular eczema of obscure or unknown etiology, occurring mostly on the dorsal surfaces. Very often such eruptions will be permanently cured with one semi-intensive or subintensive application, or a few fractional treatments. The same is true of eczema orbiculare and the type described by Pollitzer.

Of especial interest is the hyperkeratotic (parakeratotic) and fissured eczema of the palms and soles of obscure or unknown etiology. As a rule this type of eczema will disappear promptly under fractional, semi-intensive or subintensive irradiation. Some cases are very recalcitrant, some will not improve and recurrences are common. If the eruption does not respond to a reasonable amount of treatment, irradiation should be discontinued, for a continuation of such treatment may destroy the coil and sebaceous glands, leaving the skin rough and dry, without curing the eczema.

It is often necessary to irradiate the entire palmar surface of the hands and fingers, or the plantar surfaces of the feet and toes. For technical details of the method of application of *x*-rays to surfaces of this kind the reader is referred to the chapter dealing with hyperidrosis.

Eczema of the Nails.—This affection can be at times cured with *x*-rays and radium and at times the disease will not improve. However, the results have been of a nature to warrant a trial in all cases. For technical details the reader is referred to onychomycosis.

GENERAL CONSIDERATIONS AND SUMMARY.

We have now considered the effect of irradiation on the various clinical entities belonging to the eczema group and also certain regional types of the disease. It remains to discuss briefly the effect of irradiation on eruptive types of the affection—acute and chronic, localized and generalized eczema of uncertain or unknown etiology.

Eczema Erythematosum.—Irradiation has not given good results in acute erythematous and edematous eczema. In fact such treatment, unless very mild, may increase the edema. Especially is this true of the eyelids and cheeks. If there is not much edema and the subjective symptom is itching rather than stinging or burning, a few very mild applications (subfractional) may be beneficial.

As a general proposition, both in localized and generalized acute erythematous eczema, irradiation is contra-indicated in the early stage

FIG. 127.—Vesiculo-squamous eczema before treatment.

FIG. 128.—Same patient shown in Fig. 127, after four fractional treatmen

of evolution. If the eruption persists, and becomes pruritic, exudative, acanthotic or squamous, *x*-rays are indicated and may accomplish a great deal of good.

Eczema Vesiculosum, Pustulosum and Exudativum.—Exudative eczema may begin as an acute erythematous and edematous, vesicular or pustular eruption, or it may evolve subacutely or it may constitute an exacerbation occurring in a chronic eczema. Eruptions of this kind, especially when restricted in extent, often disappear more quickly under the influence of *x*-rays or radium than with any other method of treatment. The results are often spectacular and permanent. The outcome will depend partly upon the technic but largely upon the cause. If the etiological factors continue to operate the eruption is likely to be uninfluenced or only slightly influenced by roentgenization. These statements apply also to follicular and papular eczema.

Eczema Squamosum.—The chronic types of eczema associated with parakeratosis and acanthosis will disappear quickly as a rule under the influence of *x*-rays or radium. The rapidity and permanence of the cure will depend largely upon the underlying causes.

Value of Irradiation in Eczema.—Considered as one of many remedies used in the treatment of eczema, omitting types of eczema for which there are specific topical remedies, and visualizing the disease in a very general way, it is the author's opinion that *x*-rays (or radium) is the best remedy we have for eczema. In a general way it is our best antipruritic and our best resolvent agent for this purpose. However too much must not be expected. It is absolutely essential that everything possible be done to determine and eliminate the external and internal causative factors. Also, the patient should receive the benefit of regular dermatological treatment, intelligently administered, care being taken not to use strong tar, mercury, sulphur and other compounds when employing the *x*-rays.

General Technical Suggestions.—The acute types of eczema even when localized, should receive very mild applications (subfractional). Widespread eruptions of any type should receive subfractional or fractional treatment. When treating generalized or universal eruptions not more than one small part of the body should be treated daily. If this suggestion is not followed the eruption may get worse, there may be cutaneous or constitutional toxic symptoms and the lymphocytic count may be lowered.

Circumscribed subacute or chronic eruptions and even acute exacerbations may be treated with fractional, semi-intensive or subintensive doses with equal results. When the stronger doses are given all stimulating and irritating topical remedies are contra-indicated. For further technical details the reader is referred to the chapter on General Therapeutic Considerations.

In the author's experience filtered *x*-rays are no more efficacious than is unfiltered radiation even in eruptions that show considerable parakeratosis and acanthosis.

Radium.—Radium is not suitable for widespread eruptions. In the case of small patches the results of radium treatment are the same as those obtained with x-rays. Radium is especially indicated, as mentioned supra, for the treatment of eruptions situated on the scrotum and eyelids. If the skin is only slightly thickened an unfiltered radium applicator may be employed. If, however, there is considerable thickening of the skin it is preferable to eliminate the "soft" beta rays by a suitable screen (see chapter on Radium Technic).

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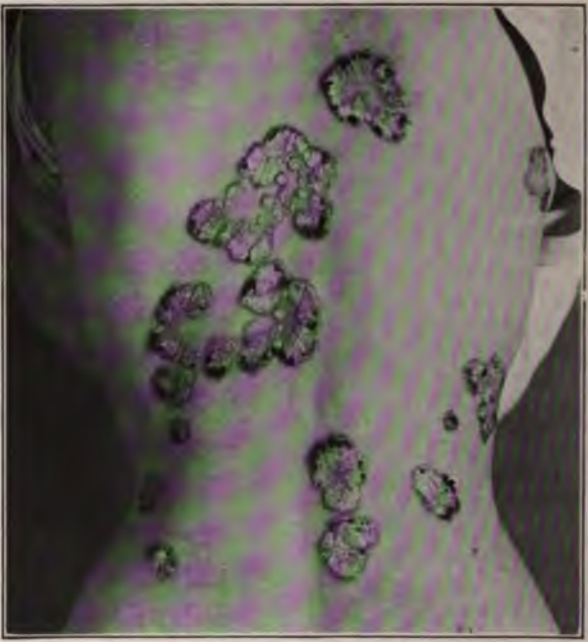

FIG. 129.—Annular, gyrate, and nummular psoriasis before treatment.

FIG. 130.—Same patient shown in Fig. 129, after fractional *x*-ray tre
The tanning is due to the disease.

when recurrent outbreaks are irradiated the disease may, after several such attacks, fail to be influenced by further irradiation. All these facts are of the utmost importance and should be borne in mind.

Sensitiveness of Lesions.—Psoriatic lesions are usually very sensitive to *x*-rays and radium. Not only do they disappear quickly under the influence of small doses, but they react more readily to such treatment than does the normal skin. A suberythema dose may produce a first or even a mild second degree reaction in the lesion while the surrounding skin will not react to the same quantity. This difference in susceptibility is caused, presumably, by the amount of blood in the lesion and, also, because psoriatic lesions are so often treated with chemicals (chrysarobin, etc.) which make the tissues more sensitive (see chapter on Idiosyncrasy). For these reasons it is advisable to always employ small doses, especially when treating patients who have been using chrysarobin, pyrogallic acid, salicylic acid, mercury, etc. Furthermore, such topical remedies are contra-indicated while the patient is under *x*-ray or radium treatment.

Effects at a Distance.—It has been claimed by G. H. Fox, Sibley and others that irradiation of one or a few lesions may result in the disappearance of lesions not exposed to the *x*-rays. The author has not found this to be true, at least this phenomenon has not occurred in a single one of several hundred cases treated with *x*-rays and radium.

Recalcitrant Eruptions.—If the lesions of psoriasis will yield to irradiation they will nearly always disappear under the influence of a few fractional (3 to 8 fractional treatments at weekly intervals) or one or two semi-intensive or subintensive applications. If the lesions do not yield to this amount of irradiation they will not, as a rule, be benefited by further treatment, therefore a continuation of treatment beyond this point is inadvisable. Long-continued irradiation of recalcitrant lesions may be followed by a peculiar resistance on the part of the disease to any form of treatment. Lapowski, at various meetings of the Dermatological Section of the New York Academy of Medicine, has repeatedly called attention to this phenomenon. The author is not certain that this peculiar stubbornness is the result of roentgenization. That it is occasionally encountered subsequent to roentgenization does not constitute proof, because equally rebellious examples of the disease are encountered in which the lesions have never been treated with *x*-rays or radium. However, the main point to be emphasized is that no good can be accomplished by a continuation of treatment beyond the point mentioned supra; in fact the result may be injury to the skin such as atrophy and excessive dryness.

The author has seen atrophy, persistent scaliness and permanent, excessive dryness of the palms caused by the too persistent irradiation of recalcitrant psoriasis of the palms. In other words the result of the treatment was an uncomfortable and incurable condition of the skin, a condition much worse than the disease for which the treatment was given.

Recurrent Eruptions.—Good judgment is required in using *x*-rays and radium for the treatment of recurrent attacks of psoriasis. This pertains to both circumscribed and generalized eruptions. Assuming that the eruption disappears, as is usually the case, as a result of a few fractional treatments, it is permissible to treat recurrences in the same manner so long as the lesions continue to respond favorably to a few small doses and the recurrences are several months apart, or the new lesions develop in locations that have not been irradiated at all or for several months. It should be recalled that four to six subintensive treatments or four to six months of fractional treatment, providing such treatment is continuous, may in some persons result in marked atrophy of the sudoriferous and sebaceous glands. Therefore, if the relapses accur in rapid succession, so that there is no opportunity to allow a rest interval of several months between courses of treatment, it is necessary to watch the skin carefully for evidence of lessened activity of the appendages.

FIG. 131.—Inveterate psoriasis before treatment.

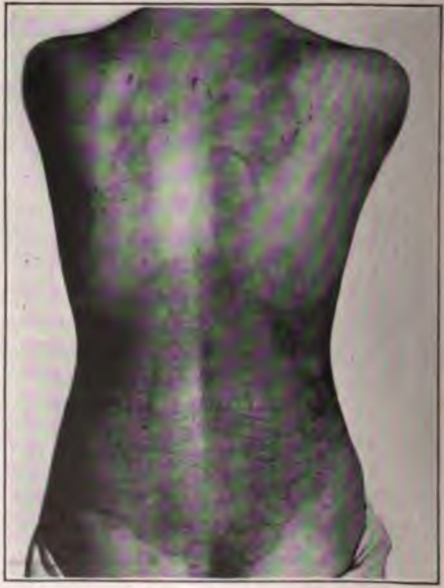

FIG. 132.—Same patient shown in Fig. 131 after fractional *x*-ray treatment. The tanning is due to the disease.

As a matter of fact it will be usually found that in cases exhibiting a tendency to prompt and frequent relapses, the eruption will cease to be benefited by continued irradiation.

Generalized Eruptions.—Generalized eruptions must be treated with caution. If the dose is too large or if too extensive areas are exposed at one time, the result may be systemic toxemia, toxic rashes, or the

psoriasis may assume troublesome and even serious characteristics. In some persons psoriasis, even when untreated, may acquire unusual and alarming qualities. One must not, therefore, thoughtlessly blame the treatment for complications of this kind. However, the fact that psoriasis can be made worse and that local and general toxic symptoms may be produced by injudicious treatment, demands caution and judgment. These statements apply not only to *x*-rays and radium, but to other forms of treatment and to combined treatment. For technical details relative to generalized roentgenization the reader is referred to the chapter on General Therapeutic Considerations.

FIG. 133.—Psoriasis universalis or dermatitis exfoliativa before treatment.

FIG. 134.—Same patient shown in Fig. 133, after universal roentgenization.

Dosage.—The author prefers small doses for psoriasis. In treating generalized eruptions the dose is fractional or subfractional depending upon the age of the patient, the extent of the involved surface and the character of the eruption (acute or chronic in type). Circumscribed areas are treated with fractional doses regardless of the clinical type. Long experience has demonstrated that small doses give better results in psoriasis than do large doses, excepting when dealing with a few small lesions. Reasons for this preference have been given supra. Subintensive treatment gives excellent results in small lesions but no better than do fractional treatments. H. Fox believes the opposite to be true. He has made stubborn lesions disappear with large doses that failed to be benefited by small doses. The author has time and

time again treated one lesion with fractional doses and a similar lesion on the same patient with suberythema doses and always the result has been about the same, providing that the total fractional dose administered in one month is a little more than that given for the subintensive dose. As an example assume that H¾ S. D. is applied to one lesion and H¼ S. D. is applied to another lesion each week for four weeks. As a rule the efficacy will be the same. Even if we assume that semi-intensive and subintensive treatments are slightly superior to fractional treatment, the difference is not great, and they can be used only for localized eruptions.

Erythema doses, *i. e.*, a quantity sufficient to evoke a first degree radiodermatosis will, as a rule, effect a better temporary result than will smaller doses. These large doses, however, may produce telangiectasia. Such treatment is never advisable. Even when employing fractional treatment a first degree reaction should be avoided if possible.

When treating small lesions it is advisable to shield the normal skin. When treating large surfaces it is not necessary to protect the normal skin. The doses used in this disease are or should be too small to injure unaffected skin.

Routine Treatment.—Small lesions, if not acutely inflamed, may be treated with fractional, semi-intensive, or subintensive doses. Circumscribed areas are treated with fractional doses. Generalized and universal eruptions receive subfractional to fractional doses.

If the eruption does not involute as a result of a few fractional treatments, if new lesions are constantly developing, or if fresh outbreaks continue to occur, it is inadvisable to continue *x*-ray treatment.

Inflamed areas are not irradiated until the acute symptoms have subsided. The use of chrysarobin, pyrogallic acid, tar, mercury, sulphur, salicylic acid, etc., is not permitted during nor for a week or two previous or subsequent to irradiation.

Practically, irradiation is of service in cases that resist other methods of treatment, for patients who have only occasional lesions or occasional attacks, and for patients who prefer to escape using disagreeable ointments. As pointed out by H. Fox, the method is particularly appropriate for psoriasis of the hands and face where chrysarobin and pyrogallic acid cannot be employed.

At a meeting of the New York Dermatological Society for December, 1920,[1] there was an excellent discussion relative to the value of roentgenization in the treatment of psoriasis. Williams, Wise, G. H. Fox, H. Fox, Whitehouse, Highman, Fordyce, and Winfield all made pertinent remarks. The reader should peruse this discussion. The gist of the discussion was that in a recurrent disease like psoriasis *x*-rays should not be employed as a routine, but only by one who knows the disease and its characteristics and, also, one who is an expert roentgenologist. It was admitted that when properly employed and

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[1] Arch. Dermat. and Syph., 1920, II, 2, p. 260.

used in selected cases, roentgenization was a safe, efficacious and clean method of obtaining relief from disagreeable objective symptoms, and in gaining control of the disease. A good point was mentioned by Winfield who warned against allowing the patient to select the treatment. A patient might obtain a good result with *x*-rays and then insist upon having every subsequent attack treated in the same manner, even going, perhaps, to ignorant or unscrupulous physicians for the purpose. Or the patient might deny having had previous *x*-ray treatment. Arsenical treatment offers an analogy. Patients are given arsenic for an attack of psoriasis. Every time a lesion develops they take arsenic without, perhaps, consulting a physician. Many such patients develop arsenical sequelæ.

REGIONAL PSORIASIS.

Psoriasis of the Scalp.—Most excellent results may be obtained with *x*-rays in obstinate psoriasis of the scalp, especially when the entire scalp is involved. The manner of application consists of the Kienböck-Adamson five-exposure method, the details of which will be found under the heading of Tinea Tonsurans. The dose must not exceed H½ S. D. in one month. This amount may be applied at one sitting or one may give H⅛ twice weekly for two weeks, etc. One course of treatment usually suffices, if not, a second course may be given after a rest interval of one month. The dose of H½ S. D. must not be exceeded as H¾ S.D. has been known to effect a defluvium of scalp hair in a female blond with psoriasis of the scalp. If two or three courses of treatment do not effect involution of the eruption it is advisable to discontinue the treatment.

Psoriasis of the Face.—For technical details relative to the application of *x*-rays to the face and neck the reader is referred to acne vulgaris and sycosis. If there are lesions on the eyelids and in the eyebrows, these parts may receive as much as H½ S. D. in a month, without danger of the hair falling out.

Psoriasis of the Hands and Feet.—It is often necessary to expose the dorsal and palmar surfaces of the hands, and the dorsal and plantar surfaces of the feet. It is possible to treat both palms or both dorsal surfaces of the hands at the same time. The same is true regarding the plantar and dorsal surfaces of the feet. This method does not provide uniform dosage over such large areas, but in the case of psoriasis uniform dosage is not necessary (for technical details see hyperidrosis).

Psoriasis of the Nails.—Irradiation yields excellent results in psoriasis of the nails. Lesions of the nails are more recalcitrant than are those of the skin. It usually requires from six to a dozen or more fractional treatments or the equivalent in semi-intensive or subintensive treatments to effect the desired result. The skin around the nails should be shielded. For further technical details the reader is referred to Onychomycosis.

Psoriasis of the Scrotum.—Psoriatic lesions usually disappear so promptly when irradiated that in ordinary cases there is no danger to the testicles. Lesions of the scrotum do not require more than three or four fractional doses, as a rule, and the amount is not sufficient to injure the testicles. However, possible injury to these organs must be kept in mind. It is advisable not to apply more than six or eight fractional doses and the course should not be repeated for at least a month or two. It is often necessary to expose the entire scrotum. This requires a dose to both the anterior and the posterior surface. Under such treatment the testes will receive a double exposure. In such instances it is advisable to limit the treatment to three or four fractional doses.

An unscreened flat radium applicator offers certain advantages when treating psoriasis of the scrotum. The "soft" beta rays act very superficially and also very rapidly. The exposure is so short that the dose of gamma rays received by the testes is exceedingly small.

Leucoderma Psoriaticum.—Rarely, after the involution of psoriatic lesions, the area of skin, previously the site of the lesion, is whiter than is the normal skin of the patient. Around this white area there is an areola which is darker than the normal skin. The dark area accentuates the white area. The affection is permanent or at least it lasts for a very long time. Irradiation should not be blamed for this peculiar sequela.

Filtration.—The author has experimented with filtered *x*-rays in the treatment of psoriatic lesions of all types. The results were exactly the same as those obtained with unfiltered radiation.

Radium.—Radium is not suitable for widespread psoriasis. Small lesions disappear quickly as a rule when treated with beta rays or gamma rays. As far as can be determined both *x*-rays and radium are equally efficacious. When treating lesions having a thick horny layer, the "soft" beta rays should be eliminated by suitable screening. If the scales are first removed an unscreened applicator may be used, although it is advisable, as a rule, to use a thin screen, say $\frac{1}{10}$ mm. of aluminium or its filtering equivalent in some other substance, in all cases, excepting when treating lesions situated on the scrotum or eyelids.

In a general way the discussion of the *x*-ray treatment of psoriasis will answer for radium when used for the same purpose. This includes, also the question of dosage. For further technical details the reader is referred to the chapter on Radium Technic.

DERMATITIS EXFOLIATIVA.

No references have been found in the literature relative to the treatment of this affection with *x*-rays. Several years ago the author treated a patient who had the primary type of dermatitis exfoliativa. The eruption was recalcitrant but it finally disappeared, either spon-

taneously or as the result of several months of fractional *x*-ray treatment. A relapse occurred in a short time and further treatment had no effect. Three additional cases were treated without the slightest improvement. Two were of the secondary type while there was some doubt relative to the third case although it, too, was probably secondary to psoriasis or eczema.

One other patient was successfully treated with *x*-rays for a generalized psoriasis. A year later the psoriasis returned and became almost universal—a secondary dermatitis exfoliativa. This eruption also disappeared as a result of irradiation. Two years later the universal eruption again appeared. *X*-rays had no effect. Autoserum and a 1 per cent. chrysarobin ointment produced a clinical cure. One year later there was another relapse, the most severe of all. This attack lasted for many months and finally disappeared while the patient was taking large doses of quinine.

The *x*-rays are, therefore, of uncertain value in primary and secondary types of dermatitis exfoliativa and also in the transition stage between psoriasis and exfoliative dermatitis.

PARAPSORIASIS.

Wise treated a case of generalized parapsoriasis of the lichenoid type (unpublished). All lesions were given four treatments at weekly intervals consisting of H¼ S. D. unfiltered. There was marked improvement—about 65 per cent.; after eight treatments nothing but a few papules and pigmented macules remained on the arms. Ormsby tried roentgenization in a case of parapsoriasis of this type and also in a case of erythrodermie pityriasique en plaques disseminées (parapsoriasis in plaques) without result. Wise and Rosen failed to note improvement in a case of parapsoriasis in plaques under rather prolonged irradiation. The case was one that resembled the premycotic stage of mycosis fungoides. The fact that the eruption failed to improve under the influence of *x*-rays was used by these writers as evidence in favor of a diagnosis of parapsoriasis. Mycosis fungoides is exceedingly amenable to *x*-ray treatment, especially in the early stages of evolution.

Maki found *x*-rays of value in the treatment of parakeratosis variegata. The original article is not available and the abstract does not give details.

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CHAPTER XXIV.

LICHEN PLANUS.[1]

Scholtz (1902) was the first to enter the literature with the report of a case of lichen planus treated with x-rays. Additional cases, in all of which the results were favorable, were soon reported by Zeisler, Edwards, Pusey, Gilchrist, Allen and many others.

These reports all related to the x-ray treatment of circumscribed patches of chronic lichen planus and lichen planus hypertrophicus.

Lustgarten (1904) obtained good results with x-rays in generalized lichen planus. Montgomery (1906) cured a patient who had a universal and very severe lichen planus. The patient had not been entirely free of the eruption for seventeen years. The eruption had been universal for several months. It disappeared as a result of irradiation over a period of three months.

Modern literature contains few references of importance. Knox dismisses the subject with a single sentence. While most text-books on dermatology and roentgenology state that the x-rays are useful in the treatment of chronic types of lichen planus, the subject has not received the attention it deserves. Blaschko, H. Fox, Wise, Stern and others have testified to the efficacy of the x-rays in localized and generalized lichen planus. Incidentally Ormsby cured a case of lichen planus atrophicus with x-rays.

Wickham and Degrais seem to have been the first to report the treatment of lichen planus with radium. They cured isolated patches of chronic lichen planus in several patients. They also cured one case of zosteriform lichen planus. Simpson, Newcomet, Finzi and others recommend radium but have little to say about the subject.

The literature has been looked over rather carefully and in view of the very marked efficacy of x-rays and radium in the treatment of lichen planus it is rather astonishing to note the paucity of good articles dealing with this subject.

Types of Lichen Planus.—Lichen planus usually develops slowly and runs a chronic course. The sites of predilection are the flexor surfaces of the forearms, the inner aspects of the thighs, the glans penis and the buccal mucosa; but almost any part of the body may be involved; the eruption in fact, may be generalized. The elementary lesion is a pinhead-sized, flat-topped, shiny, smooth, more or less polygonal, sometimes umbilicated papule. The color is lilac—violaceous. The

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

subjective symptom is itching which may vary from mild to intense. The papules may be discrete or they may be grouped into large patches of eruption. They may coalesce into a solid patch of lichenification—a mosaic. They may form linear, annular and gyrate configurations.

Lichen planus, untreated may last for months or years. Individual lesions may persist or the eruption may continue to exist through the formation of new lesions, the older lesions undergoing spontaneous involution. It seems to be the general consensus of opinion that the spontaneous cure of lichen planus is uncommon. This, however, is not the author's impression. While not desiring to make a definite statement, personal impression is that many if not most cases of ordinary lichen planus will disappear without treatment in from four months to a year or two.

Individual papules of lichen planus may at times increase markedly in size or individual patches may become thickened—lichen planus hypertrophicus. Such patches may become hyperkeratotic or verrucous—lichen planus verrucosus. These types are exceedingly persistent and recalcitrant and are situated usually on the legs. They may persist almost indefinitely.

Occasionally lichen planus may develop rapidly as an acute exanthem with a generalized or almost universal distribution. In such instances the elementary lesions are so tiny and so closely crowded that they are likely to be overlooked. The color is a dull crimson; there may be slight scaliness; the subjective symptom is a very distressing combination of burning and itching.

There are other types of lichen planus, but we are concerned only with the varieties that are known to be amenable to irradiation. For further details relative to clinical types the reader is referred to standard text-books on dermatology and to articles by Little, White, and Fordyce and MacKee.

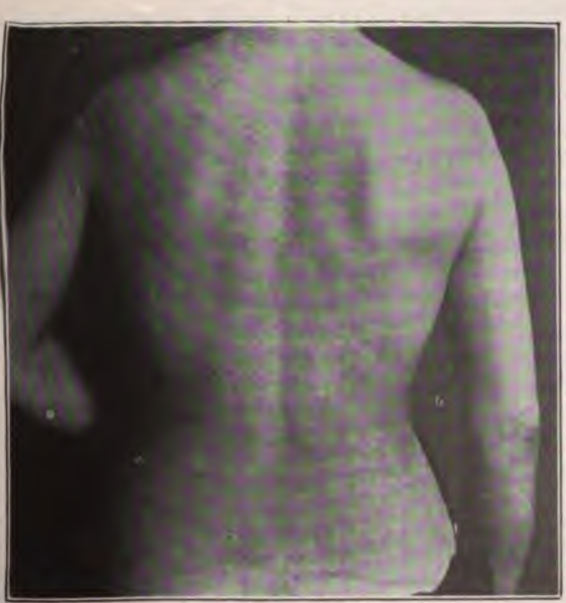
Lichen planus of the mouth may simulate leukoplakia and inasmuch as the technical requirements are different in the two diseases correct diagnosis is of the utmost importance. Lichen planus is recognized by reticulation of the mucous membrane eruption and by a concomitant eruption of the skin.

Effect of Irradiation.—The result of *x*-ray and radium treatment will depend upon the various characteristics of the eruption.

Acute Exanthem Type.—The author has treated three cases of this type with *x*-rays. The results have been excellent. The worst and most interesting case was referred for roentgenization by John Lane, of New Haven. With the exception of the scalp and face, the eruption was universal. The eruption consisted of one solid sheet of confluent, tiny papules which could be seen only with a side light. The color was a dull crimson. The subjective symptoms were burning with intense itching. The eruption had been present for six months and had not improved under arsenic and mercury by ingestion. The very first *x*-ray treatment lessened the itching and burning. These symptoms

d rapidly and entirely disappeared in less than three weeks. ption showed evidence of involution after the first treatment.

135.—Generalized lichen planus of the acute type before treatment.



136.—Same patient shown in Fig. 135, after generalized roentgenization.

The involution was continuous. The patient was cured and discharged in seven weeks. There has been no relapse since 1917.

The second patient had a mild attack of lichen planus which disappeared in two months. One month later there was an acute universal eruption which continued unchanged for four months when *x*-ray treatment was begun. The patient was cured in six weeks. There has been no evidence of the disease for nearly two years. Roentgenization proved especially efficacious in the third patient.

Generalized Lichen Planus.—In the past ten years (clinic and private) 30 patients with generalized lichen planus have been treated with *x*-rays. The eruption has varied in extent, sometimes being widely distributed over the extremities, sometimes involving the back, chest and abdomen. In every instance the eruption has disappeared promptly as a result of *x*-ray treatment, usually in a few weeks. Most of the patients remained well. In a few there were relapses. One patient continued to develop new lesions over a period of two years in spite of *x*-rays, arsenic and mercury. The outcome of this case is unknown.

Localized Lichen Planus.—Localized patches of ordinary lichen planus involute rapidly when irradiated. One or two suberythema doses or from four to eight fractional doses usually suffice for a cure. New lesions may develop in the site of the former eruption or in new locations. This is not, however, the rule. It must not be inferred that irradiation prevents recurrence or that it exerts any influence on the unknown etiological factor. All that can be said is that irradiation will cause prompt disappearance of the lesions.

Eighty-seven cases of localized lichen planus have been treated with *x*-rays. Many of these cases were of the hypertrophic type, a few were of the verrucous variety; 1 patient presented a hypertrophic lichen with lesions as large as a split walnut (Dr. Whitehouse's patient).

The results obtainable in hypertrophic lichen planus depend upon the duration of the eruption and the thickness of the tissue. One erythema or suberythema dose, or from four to eight fractional doses will usually cause complete involution of individual hypertrophic papules and small patches of hypertrophic lichen planus. Large, thick patches are more stubborn and may require irradiation, intensive or fractional, over a period of two or three months.

Verrucous lichen planus is comparatively very recalcitrant, often requiring from three to six intensive doses, depending of course upon the size of the lesion and the amount of acanthosis and hyperkeratosis.

The patient with the tumor-type of lichen received two intensive applications but failed to remain under observation. When last seen there was some improvement.

Lichen planus of the mucous membranes disappears very quickly when treated with *x*-rays or radium. Four cases of lichen planus of the glans penis, 2 cases with lesions on the lower lip, 2 cases with lesions on the dorsal surface of the tongue, and 4 cases with

eruption on the mucous surfaces of the cheeks were cured or two intensive or subintensive treatments. Most of these were treated with radium.

IG. 137.—Annular and pigmented lichen planus before treatment.

38.—Same patient shown in Fig. 137, after eight fractional treatments.

Irradiation vs. Arsenic and Mercury.—It is the general consensus of opinion among dermatologists that mercury and arsenic are very efficacious in most of the cases of lichen planus. Many men are enthusiastic over the results obtained with these drugs. However, there is no unanimity of opinion. White, in an excellent article, states: "It is an aphorism in clinical medicine that the greater the number of drugs recommended in the treatment of a disease, the less satisfactory are any of them therapeutically. Thus the long list of drugs used well illustrates my evident inability to master the cure of lichen planus. In fact I must acknowledge my pessimism. In truth, I must freely confes that in my opinion we have no internal remedy worthy of the name.' White also avers that "roentgen rays, in my experience, have proved broken reed to lean on."

FIG. 139.—Lichen planus hypertrophicus before treatment. The lesions on the wrists represent hypertrophic lichen planus papules. The lesion on the little finger is one of verruca vulgaris.

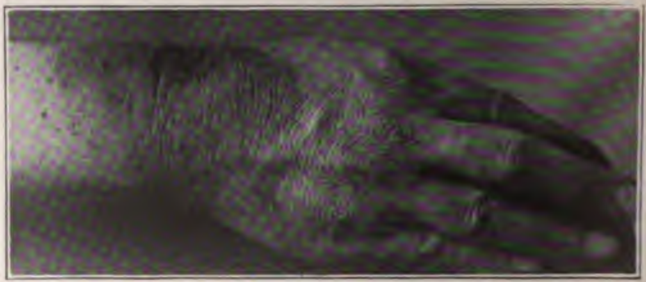


FIG. 140.—The same patient shown in Fig. 139, after one intensive x-ray treatment. The wart on the little finger was untreated but it disappeared in less than a month after the treatment of the lichen papules.

Zeisler, Hartzell, Pusey, Trimble, Pollitzer, and Lieberthal, in di cussing the articles by Little, and White, all agreed that arsenic ar mercury were very useful remedies. Little obtains very quick resul with enesol (a combination of arsenic and mercury) in 2 c.c. do administered by injection every second day for about six weeks.

most cases itching ceases in about a week and the eruption disappears in about a month or six weeks. Ormsby finds that a dozen injections of bichloride of mercury will cure ordinary cases. Pollitzer obtains

FIG. 141.—Lichen planus hypertrophicus.

FIG. 142.—Same patient shown in Fig. 141, after twelve fractional treatments.

quick results with injections of arsenic. Salvarsan has been used by a number of men with indifferent results.

The author has not administered arsenic and mercury by hypodermic injection in cases of lichen planus. His results with these drugs when given by ingestion have not been satisfactory. In reading over the literature dealing with the treatment of lichen planus and noting the large number of drugs advocated by different men for internal administration and external application, including advice relative to hygiene, rest, diet, etc., one is impressed with the fact that the disease is hard to cure and that the action of arsenic and mercury is uncertain.

The author has gained the impression that many cases of ordinary lichen planus will disappear spontaneously in from four to eight months and as it usually requires this length of time for a cure with arsenic or mercury (by ingestion) the inclination is to question the efficacy of these drugs when used in this manner.

Irradiation will cause the prompt involution of lichen planus eruptions. It affords quick relief from itching. Although recurrences are not common it cannot be said that irradiation does more than relieve subjective and objective symptoms. Practically, irradiation is effective in all cases and the relief is obtained more quickly than by any other method of treatment other than the hypodermic administration of arsenic and mercury as advocated by Little, Pollitzer, Ormsby and others. If such treatment is effective in the majority of cases of ordinary lichen planus it is, then, the method of election. If not, it must give way to irradiation.

At the present moment it seems unwise to advise *x*-rays as a routine treatment in cases of generalized lichen planus. They should, however, be employed in case the eruption does not respond promptly to injections of arsenic and mercury. Combined treatment seems advisable in many cases.

It seems preferable to employ *x*-rays or radium for localized patches of lichen planus rather than depend upon constitutional remedies.

Concluding this phase of the subject it may be said that *x*-rays constitute the best remedy we possess for external use in the treatment of generalized lichen planus. Radium and *x*-rays are of equal efficacy for circumscribed areas of disease. There is and will be for some time, a controversy relative to the comparative efficacy of *x*-rays and radium on the one hand, and arsenic and mercury on the other hand.

Sequelæ of Lichen Planus.—Lichen planus may be associated with very marked pigmentation. At times this staining or pigmentation may persist for several months after the eruption has disappeared. Lichen planus sclerosus (lichen planus atrophicus; lichen planus morpheicus) leaves areas of atrophy, depigmentation or scars. Scarring may also occur in the vesicular type of lichen planus, and pigmentation and scarring may be produced traumatically (scratching) in ordinary lichen planus. *X*-rays and radium should not be blamed for these sequelæ.

Technic.—*Generalized and Universal Eruptions.*—The method of applying *x*-rays to extensive surfaces or to the entire body is described in detail in the chapter on General Therapeutic Considerations. In acute cases the dose should be H$\frac{1}{8}$ S. D. once weekly; in chronic types, H$\frac{1}{4}$ S. D. once weekly.

Eruptions that are not generalized but which occupy fairly extensive surfaces, such as the entire forearm, may be treated with fractional or semi-intensive applications.

Circumscribed Eruptions.—Small patches of ordinary lichen planus seem to respond equally well to fractional or suberythema doses. These eruptions disappear very quickly under the influence of full erythema doses, but such treatment is unnecessary and inadvisable.

The author prefers intensive treatment for hypertrophic lichen planus. These lesions will tolerate full erythema doses on account of the thickened epidermis. As soon as the hyperkeratosis and acanthosis are diminished, the dose should be reduced in size. The very thick horny layer of lichen planus verrucosus will permit hyperintensive applications, at least until the horny layer and rete are reduced in thickness. When employing these large doses the normal skin must be adequately protected with lead foil or other suitable material. For details relative to the application of *x*-rays to convex and concave surfaces and to lesions of various sizes, the reader is referred to the chapter on General Therapeutic Considerations.

Filtration.—Filtration of roentgen radiation is of no value in the treatment of lichen planus of the ordinary types. It may be used to advantage when treating the hypertrophic or verrucous type of the disease.

Radium.—Flat applicators give excellent results in localized patches of lichen planus. No filtration is necessary for mucous membrane lesions or for very flat patches in the skin. If the lesions are infiltrated, a screen of about $\frac{1}{10}$ mm. of aluminium is advisable in order to eliminate the "soft" beta rays. When treating hypertrophic or verrucous lesions it is preferable to use only the gamma rays. What has been said relative to the *x*-ray treatment of lichen planus applies in general to the use of radium for the same purpose. For technical details the reader is referred to the chapter on Radium Technic.

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CHAPTER XXV.

PRURITUS. PRURIGO.[1]

THE analgesic and antipruritic properties of x-rays were early recognized. The earliest text-books called attention to these attributes of the radiation (Freund, Pusey, Williams, Belot, Allen, etc.).

For many years it was thought that x-rays were a powerful and useful analgesic for the relief of pain. Hence we read of the apparent benefit of such treatment in cases of zoster, sciatica, neuritis, rheumatism, neuralgia and many other diseases in which pain is a prominent symptom.

Stembo reported 28 cases of neuralgia with 75 per cent. of cures in three treatments. Grunmach found x-rays useful in intercostal and facial neuralgia. Freund and Gocht report the cure of a case of severe trigeminal neuralgia of ten years' duration. Wickham and Degrais, Newcomet, Schiff, and others testify to the analgesic action of radium in herpes of different types including zoster, and neuralgia. Newcomet gives C. L. Leonard the credit for being the first or one of the first to recognize this action of x-rays on the sensory nerves.

In recent years very little is heard relative to the ability of x-rays or radium to relieve pain by direct action on the nervous system. Theoretically, such action is possible but in practice irradiation as a rule seems to be of little if any value.

Occasionally a roentgenologist will report the entire subsidence of neuralgic pain subsequent to the making of one or more roentgenograms of the affected part. Such phenomenon is, however, unusual and may or may not be due to the radiation.

The author has seen a number of patients who aver that neuralgic pain was made worse by roentgenization. In two instances pain did not develop until after roentgenograms were taken. One patient, who had had a roentgenologic examination of the accessory nasal sinuses, developed neuralgic pain in the back of the head which lasted for several weeks. There was, also, temporary alopecia.

Suffice it to say that there is very little trustworthy evidence to support the theory that x-rays or radium can lessen pain by direct action on nerve tissue. The concensus of modern roentgenologic opinion is that irradiation is not indicated in such diseases as zoster, neuralgia, rheumatism, etc. In the few instances when relief from pain is the apparent result of irradiation, it is possible that psychological influence is the basis for the analgesic action.

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

In such diseases as mycosis fungoides, epithelioma, sarcoma, adenitis, etc., *x*-rays and radium may lessen pain by promoting resolution of infiltration and exudation—indirect action. Many modern practitioners believe that *x*-rays and radium lessen the pain of epithelioma by direct action. This may be true but there are many skeptics of which the author is one.

PRURITUS.

That irradiation will, as a rule, promptly arrest the itching that accompanies such affections as eczema, lichen planus, mycosis fungoides, neurodermatitis, etc., is a well-established fact and need not be discussed here. We are now dealing with pruritus that is independent of any eruption (pruritus essentialis) although lesions or an eruption may develop secondarily as a result of rubbing, scratching and strong topical remedies.

Generalized Pruritus.—Very little is known regarding the value of *x*-rays in the treatment of widespread essential pruritus. Oulmann reports the cure of generalized pruritus (idiopathic) of ten years' duration. The itching was most marked on the chest and back. The patient was thirty years of age. Kromayer, and H. Fox have obtained good results with *x*-rays in more or less generalized essential pruritus.

The author has treated a number of cases of generalized and universal pruritus and persistent itching of large areas, of unknown etiology. The results have been encouraging, but more experience is necessary before cases can be properly selected.

At the present moment the author is of the opinion that irradiation is not indicated in widespread pruritus excepting when it is impossible to ascertain and remove the cause of the itching and when the distressing symptom continues in spite of regular dermatological treatment. In such instances *x*-rays are likely to be of real service.

The technic does not differ from that given under the headings of eczema and lichen planus. The dose should be small—H$\frac{1}{8}$ to $\frac{1}{4}$ S. D. unfiltered, once weekly.

Regional Pruritus.—All who have had considerable experience with *x*-rays and radium testify to the efficacy of these agents in the treatment of persistent itching of the vulva, anal region and scrotum. As a rule the itching will disappear entirely as a result of one or two suberythema doses or from four to eight fractional doses. Usually there is no relief for at least two weeks subsequent to the institution of treatment and complete relief is not obtained for from four to eight weeks. The treatment is almost certain to effect at least temporary relief.

The author has treated 85 cases of regional pruritus, mostly of the anus and vulva, with *x*-rays. The cause could not be ascertained in any of these cases. Two patients failed to improve even when the treatment was pushed to a mild first degree reaction. Another patient

required ten fractional treatments at weekly intervals for complete relief. The severe itching returned in a month. The patient was a highly neurotic female. She refused to submit to further roentgenization. In all the other patients the itching was arrested in one or two months and there was no recurrence for at least several months.

There is considerable doubt about the frequency of recurrence. In private practice many of the patients have a recurrence in from a few months to a year or two. The author has a number of patients who require a suberythema dose or a course of fractional treatments about once a year. In all but two patients each recurrence has disappeared promptly under the influence of x-rays. One patient finally failed to obtain relief even with an erythema dose. In another patient the recurrences are becoming more frequent and more stubborn.

The author knows of 6 patients who did not have recurrences. Most of the patients were not seen after their first course of treatment.

The impression gained is that irradiation provides the most certain method of obtaining at least temporary relief in cases of regional pruritus. It is successful in nearly every case. The relief may be permanent but recurrences are the rule. Everything possible should be done to locate and overcome the cause of the itching.

Complications.—The usual dermatological complications of pruritus, especially regional pruritus, are eczema, pyoderma and lichenification. These complications usually disappear promptly under the combined effects of irradiation, soothing topical remedies and cessation of scratching and rubbing.

Topical Remedies.—There is no objection to the use of menthol, diluted carbolic acid, camphor and anesthesin as antipruritics during the treatment, but strong preparations of oil of cade and sulphur should be avoided.

Technic.—*Pruritus Ani.*—The anal region is concave and it is desirable to flatten the area as much as is possible. This can be accomplished fairly well by having the patient lie on the stomach. The gluteal fold may be separated by the patient with his hands. To insure against motion it is preferable to separate the gluteal fold with two pieces of zinc plaster. The proximal ends of the strips are attached to the buttocks and the distal ends are fastened to the table.

The lithotomy position is also suitable for this purpose although it is less comfortable. The lithotomy position (patient on back with thighs flexed on abdomen) is the best position when it is necessary to expose the anus, the perineum and the vulva or scrotum, as is often the case.

In women it is often necessary to expose the entire region from the pubis to and including the anus. In some instances this may be done by placing the target opposite the perineum. In many patients it is necessary to make two exposures—one with the target opposite the upper part of the vulva and one with the target opposite the anus. The radiation from the two exposures is allowed to overlap upon the

perineum and lower part of the vulva. One position should be nearly at right angles to the other.

The legs, and in fact all unaffected parts, should be adequately screened.

Filtered *x*-rays offer no advantage over unfiltered radiation.

Dosage.—The dose may be either fractional or subintensive. The results appear to be the same in either case. Full erythema doses are to be avoided on account of the possibility of telangiectasia and other sequelæ. It has been the author's experience that if itching cannot be arrested by administering a quantity of radiation that is insufficient to provoke an erythema, larger doses will also fail. Also, if two or three months of irradiation does not prove efficacious, there is no use in continuing the treatment. There may be a defluvium of hair but the alopecia is usually temporary.

Pruritus Vulvæ.—The technic for irradiating the vulva is given under the preceding heading. The patient should understand that there may be a temporary loss of hair and that, if the affection is recalcitrant, the loss of hair may be permanent. There is no danger to the ovaries with the dosage used in practice for this purpose. Occasionally it is necessary to separate the labia majoræ. This the patient may do herself with the fingers or the parts may be held apart by means of zinc plaster.

Pruritus Scroti.—In treating pruritus of the scrotum with *x*-rays care must be had not to injure the testes. It is safe to administer from four to six fractional, unfiltered treatments to both the anterior and posterior surfaces of the scrotum. If more than this amount of radiation is required, as is very often the case, the semen should be examined at weekly intervals and the patient should be told of the possibility of azoöspermia. Even when it is necessary to push the treatment to the point of reducing the spermatozoa numerically or to complete azoöspermia there will, as a rule, be complete regeneration upon cessation of treatment. It is possible, of course, to effect permanent azoöspermia. The exact quantity necessary for this purpose is unknown to the author. The roentgenologist should not accept this responsibility. In every recalcitrant case the patient should be made acquainted with the risk, his semen should be examined before institution of treatment and at frequent intervals during the treatment. Men who have suffered for years with severe pruritus scroti will, as a rule, willingly assume the risk of permanent azoöspermia, especially if they are beyond middle life as is likely to be the case.

An unscreened, flat, radium applicator would seem to be especially suitable for the treatment of pruritus scroti. A full-strength unscreened applicator applied for from three to five minutes to one area after another until the entire scrotum has been treated, will often suffice for a clinical cure. If not, the treatment may be repeated in three or four weeks. The quantity of gamma and "hard" beta rays reaching

the testicle will be insufficient for the production of azoöspermia. Furthermore, when applying radium to any one part of the scrotum, the testicle can be pushed to one side.

It is usually necessary to apply *x*-rays to both the anterior and the posterior surfaces of the scrotum. This may be accomplished by having the patient lie on his back. The scrotum is held in contact with the abdomen by the patient's fingers. The fingers, of course, should be shielded. An exposure is now made to the posterior surface of the scrotum. The posterior surface is now allowed to rest on a folded towel which is placed between the legs, and the anterior surface is irradiated.

Radicular Roentgen Therapy.—Zimmern and Cottenot recommend what they term "radicular radiotherapy" for pruritus and neuralgia. The method consists of applying *x*-rays to the region of the emergence of the spinal nerves. They claim success in sciatica, brachial neuralgia, neurodermatitis and psoriasis.

Radium.—The use of radium for the treatment of pruritus scroti has been already discussed. The author has had very little experience with radium in regional pruritus essentialis of other parts. Occasionally he has placed a tubular radium applicator in the anus together with the application of *x*-rays externally (cross-fire). Also he has tried beta rays of radium in cases where *x*-rays have failed; the results were negative. In general what has been said relative to the treatment of regional pruritus with *x*-rays pertains also to radium. For technical details the reader is referred to the chapter on Radium Technic.

Wickham and Degrais, Bayet, Schiff, Knox, Newcomet, Finzi, Simpson, Vignolo-Lutati and others have obtained excellent results with radium.

PRURIGO.

Prurigo Nodularis.—Zeisler treated a case of prurigo nodularis with *x*-rays. The case was benefited but it was not cured. Trimble failed to note relief in one case. C. J. White treated a case of lichen obtusus corneus in which a diagnosis of prurigo nodularis was considered. *X*-rays were not beneficial. There has been no personal experience with *x*-rays or radium in this rare disease, but such treatment, theoretically, should be beneficial.

Prurigo Mitis.—Schultz has roentgenized cases of prurigo of Hebra and has obtained relief from the itching and eruption for periods of from four to six weeks. Hahn, and Belot report clinical cures. Scholtz failed to note any effect in one case and improvement in several others. The author, several years ago, tried *x*-rays in a number of cases. The lichenification and patches of secondary eczema disappeared. The itching was relieved and there were fewer new lesions. The effect was evanescent. It is doubtful if *x*-rays are of any practical value in prurigo mitis excepting, perhaps, in selected cases.

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CHAPTER XXVI.

DISEASES OF THE APPENDAGES.[1]

In this chapter we will discuss hyperidrosis, bromidrosis, granulosis rubra nasi, hydrocystoma, alopecia areata, alopecia prematura, pompholyx, cheilitis glandularis and cheilitis exfoliativa. The last is not a disease of the appendages. It is similar if not identical to seborrheic dermatitis. Both forms of cheilitis are considered in this chapter solely for convenience. Many diseases of the appendages are considered in other chapters. Tinea tonsurans, tinea barbæ, onychomycosis, onychia, favus, acne vulgaris, sycosis vulgaris, hypertrichosis, oily seborrhea, alopecia cicatrisata, various types of folliculitis, etc., are contained in the various chapters and may be located with the aid of the index.

HYPERIDROSIS.

Pusey, in 1901, on theoretical grounds, suggested the use of x-rays for excessive sweating. Engman cured a case of hyperidrosis of the axillæ in 1903. In the same year Stelwagon cured excessive sweating of the palms. Since these early reports there have been many articles on this subject, the most notable of which, perhaps, is an article by Pirie who reports the permanent cure of 15 cases of hyperidrosis of the axillæ, hands and feet with from four to six intensive treatments at intervals of one month.

It is now admitted by all that roentgen therapy or radium therapy is not only efficacious in combating excessive sweating in localized areas, but that such procedure constitutes the only certain method of permanently curing the affection.

To cure hyperidrosis it is necessary to irradiate until there is considerable atrophy of the sweat-glands. When this has been accomplished there is likely to be more or less atrophy of other appendages and of various parts of the true skin. This atrophy may or may not be manifested by slight wrinkling. In any event it is deemed unwise to treat hyperidrosis of the face on account of the possibility of visible wrinkling. Slight atrophy of the skin of the face is likely to be disfiguring, especially when the person laughs or smiles. A much greater amount of atrophy will not be noticeable in the axillæ, or on the hands and feet. Furthermore, the skin of the face seems to undergo atrophy more easily than does the skin of other parts.

Hyperidrosis of the scalp cannot be treated with x-rays or radium because such treatment would probably result in permanent alopecia.

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

It is considered unwise to treat generalized hyperidrosis with *x*-rays because such an enormous amount of radiation might deleteriously effect the deep lymphatic structures, the blood, viscera, etc.

Rarely one sees localized hyperidrosis in unusual locations—cheek, forehead, or a single round area on the back or on one arm or leg. Such circumscribed areas can be successfully treated with *x*-rays or radium.

The most marked examples of hyperidrosis are usually seen in the axillæ, on the palms and on the feet, especially the plantar surfaces. The result of intelligent irradiation in hyperidrosis of these regions is perfect. It is a specific and it is the method of election.

Excessive Dryness. -It is very important not to cause complete atrophy of the sudoriferous glands. This cannot be avoided with absolute certainty, but it can be prevented in most of the cases. While it is true that an excessively dry skin is preferable to an excessively moist skin, yet the former has its disadvantages. The author has seen cases of excessively dry skin of the axillæ, palms and feet that required constant applications of grease. Without plenty of oil the skin fissured and eczematized very easily, especially in cold weather. The treatment, therefore, should proceed cautiously and it should be interrupted before sweating has entirely ceased. After cessation of treatment the secretion will usually continue to diminish for a few weeks and the skin may become temporarily too dry. This is followed by considerable regeneration, so that the end-result is a skin exhibiting the normal amount of moisture. Roughly, the treatment should be stopped when there has been 50 to 75 per cent. improvement. After a rest of two or three months, if there is still too much sudoriferous activity, more treatment may be given. Irradiation will positively cure hyperidrosis but there is no successful treatment for the excessively dry skin that may follow complete atrophy of the oil-glands and sweat-glands.

Patients will become impatient and urge the operator to administer larger doses or to give the treatments at shorter intervals. Is it necessary to caution the reader that he must be guided entirely by his own judgment which should be based on a knowledge of the disease and an adequate knowledge of *x*-rays and radium? If so, it is requested that the reader peruse carefully the medico-legal chapter. Examine the skin carefully and interrogate the patient at each visit. Stop the treatment before sweating is entirely arrested. There are instances when sweating stops suddenly after one or several treatments. In such cases no more treatment should be administered. As a rule the reduction of sudoriferous activity is gradual.

Dosage. Regional hyperidrosis may be cured in one treatment by administering a quantity of radiation that will effect a well-marked, first-degree reaction or a mild second-degree reaction. Such treatment is decidedly inadvisable. It may cause too much atrophy and it may be followed by telangiectasia. The a[illegible]een some excellent results from such treatment and he ha[illegible]w bad results.

Many roentgenologists apply fractional treatment (H¼ S. D. unfiltered, once weekly) without interruption until the desired result is obtained. This is good treatment and the results are satisfactory. Most operators give monthly treatments. The flexures (axillæ, palms and soles) are rather sensitive parts ("radiosensitive") and, therefore, the dose should be less than for other parts of the body. The soles will tolerate a little more than will the palms, and the latter will stand a little more than will the axillæ. The sex, age and complexion of the patient, must also be taken into consideration. However, the routine dose used by the author for all these locations, is subintensive and unfiltered—H¾ S. D. applied once monthly. There are exceptions: in adolescents, females and blonds the first dose is H½ S. D. In some persons the dose is H1 or even H1¼ S. D. It rarely requires more than six treatments to effect the desired result. Many patients are cured in four treatments and a few patients are cured in two treatments.

Technic.—*Axillæ.*—The patient should be on his back on the table; the forearm is placed behind the head. This will expose and tend to flatten the concave axilla. The anode is placed directly over the center of the axilla; all parts excepting the axilla are carefully shielded. In most persons it is impossible to convert the axilla into a plane surface. With the position given supra there will be still a little concavity. This slight concavity, however, is not a disadvantage as it favors equalization of dosage of the entire surface (Chapter XIX).

After the hyperidrosis is cured there is likely to be permanent loss of axillary hair. Frequently the alopecia is not permanent. Some cases may be cured without even a temporary alopecia. Most patients prefer permanent alopecia of the axillæ.

Palms.—Both palms may be exposed at one time. The hands are held close together with the dorsal surfaces of the hands and fingers in contact with the table. The anode is placed directly over the center of the area to be irradiated. It is obvious that the dose will not be equal over this large surface unless the tube is placed at a much greater distance than is used in practice. This accounts for the apparent stubbornness of hyperidrosis of the finger tips. If the hands are flexed a little so that the periphery of the exposed surface is a little nearer than is the center, then all the rays, direct and oblique, will travel the same distance and the dose will be equalized over the entire surface. It is difficult to estimate the exact amount of flexion required, and if this feature is correctly estimated it is extremely unlikely that the hands will remain in a fixed position during the exposure. If there is too much flexion the fingertips will receive too much radiation.

Pirie has devised a very ingenious apparatus for this purpose. It consists of a sheet of heavy celluloid shaped like a half bowl. The backs of the hands are placed on the operating table with the palms and fingers of both hands in contact with the convex surface of the bowl. The shape of the apparatus is based on the law: intensity varies inversely as the square of the distance or directly as the sine of the

angle of incidence. The anode is placed directly over the center of the bowl.

For further technical details the reader is referred to the chapters on X-ray Technic and General Therapeutic Considerations.

Feet.—Hyperidrosis of the feet may be confined to the soles or it may involve the lateral and even the dorsal surfaces. It is not a simple matter to equalize the dose over these uneven, convex and rather extensive surfaces.

The soles can be irradiated by having the patient lie face down on the table. The dorsal surfaces of the feet rest on the table. A sandbag placed under the ankles will add to the patient's comfort. A still better plan is to place the dorsal surfaces of the feet on an inclined plane. Both feet are held close together. The tube is placed so that the direct rays are perpendicular to the plane of the surface to be irradiated, the target being directly over the center of this surface.

This does not give equal quantity over the entire surface, but it answers practical requirements in most instances. If the feet are large, it may be necessary to treat first one-half of the planter surface and then the other half, care being taken not to expose any part of the surface twice.

If it is necessary to expose the lateral and anterior aspects of the feet as well as the soles, the following procedure may be adopted: After treating the soles the foot is placed so that its outer surface rests on the table. The target is placed over the tubercle of the navicular bone. The foot is then allowed to rest on its external surface and the target is placed over the articulation between the scaphoid and internal cuneiform bones. Each of these exposures are to be at right angles to that for the soles, and each foot is to be separately treated. No protection is necessary. The oblique rays from all the exposures are allowed to overlap. The ankles and legs, of course, should not be included in the field of radiation.

Filtration.—There is no objection to filtration, but the author has failed to note any advantage when employing filtered radiation. To give arguments for and against filtration will be but to repeat what has been said in other parts of this work. The reader is referred to the chapters on General Therapeutic Considerations, Filtered X-ray Technic, Hypertrichosis, Acne Vulgaris and Sycosis.

Radium.—The author has not employed radium in the treatment of hyperidrosis because *x*-rays are more suitable for the rather extensive surfaces that are usually involved. No literary references have been located. Unquestionably gamma or "hard" beta rays will prove as efficacious as are the *x*-rays in this affection.

BROMIDROSIS.

Bromidrosis may be general or regional. It is most often regional, the sites of predilection being the axillæ and feet. It is usually associ-

ated with hyperidrosis. Regional bromidrosis can be always greatly relieved and often entirely cured by irradiation. The technic is the same as outlined for hyperidrosis. Lieberthal cured a case of bromidrosis in 1910. Ormsby, Pusey, Sutton and many other dermatologists and roentgenologists have found *x*-rays of service in this unpleasant affection.

GRANULOSIS RUBRA NASI.

There has been no personal experience with *x*-rays or radium in the treatment of this disease. Pusey, Sutton and others suggest the use of these agents. Brandle found the *x*-rays efficacious. Winfield noted improvement with *x*-rays in one case.

HYDROCYSTOMA.

Max Joseph and Conrad Siebert cured a case of hydrocystoma tuberosum multiplex with *x*-rays.

FIG. 143.—Cheilitis exfoliativa of long standing before treatment. The patient also has a few vesicles of herpes labialis.

FIG. 144.—Same patient shown in Fig. 143, after one subintensive *x*-ray treatment.

CHEILITIS.

Cheilitis Glandularis.—Zeisler, and Sutton noted marked improvement in cases of cheilitis glandularis treated with *x*-rays.

Cheilitis Exfoliativa.—Hyde, Gilchrist, Ravitch, H. Fox, Morris, Ormsby, Sutton and others have cured cases of cheilitis exfoliativa with *x*-rays. The author has treated several cases with *x*-rays. In each instance a single suberythema dose effected a prompt clinical cure. As

far as is known there were no recurrences. Sutton cured 1 case with one application of radium.

It should be remembered that the mucous membrane of the lip is more sensitive to irradiation than is the skin of the face; therefore the dose should not be large. If a cure by a single treatment is attempted, the dose should not be over H$\frac{3}{4}$ S. D. unfiltered. Fractional treatment will undoubtedly give the same results.

POMPHOLYX.

Pompholyx (dysidrosis; cheiro-pompholyx) is a disease that is often confused with eczematoid ringworm, dermatitis venenata and eczema. For this reason one must be careful in giving evidence for or against the efficacy of irradiation in the treatment of this affection—in other words it is necessary to be reasonably certain of the diagnosis. Another difficulty is that pompholyx is a self-limited affection which may endure for a few weeks to a few months. Yearly recurrences are common.

The author has a record of 20 cases of pompholyx that were treated with *x*-rays. Most of them were given fractional treatment. A few, cases in which there was also hyperiodrosis, were given monthly suberythema doses. About all that can be said regarding the results is that the eruption in all cases disappeared in from two to four weeks. Nothing is known relative to recurrences. The impression gained is that *x*-rays are of distinct service in this disease.

Only two literary references have been found dealing with this question. Geyser reported the cure of a case in 1908. It should be stated, however, that the diagnosis was disputed by Abrahams and Gottheil. Simpson reported the cure of a case in 1913 with radium. The eruption, which was limited to the palms, disappeared in two weeks as a result of five fractional applications.

The technic of application does not differ from that given for hyperidrosis of the hands and feet.

ALOPECIA.

Modern literature contains no reference to the treatment of alopecia idiopathica, alopecia systemica, alopecia seborrheica and alopecia areata. It is the consensus of modern opinion that *x*-rays and radium are of little if any value in the treatment of these conditions.

The early literature contains many reports which seem to indicate that *x*-rays stimulate the growth of hair. Kienböck, and Holzknecht thought they obtained good results in alopecia areata with epilating doses. Others claimed success with fractional doses without pushing the treatment to the point of epilation. Later, these authors together with Neumann and others, encountered many refractory cases and realized that the few apparent successes were due, in all probability,

to spontaneous recovery. Later still, it was admitted by practically all roentgenologists that *x*-rays were useless in alopecia areata.

Bordet, in 1906, reported a case of idiopathic baldness in which a good growth of hair followed a single epilating dose. Holzknecht failed to improve alopecia seborrheica.

It is not profitable to go further with this subject. Suffice it to say that *x*-rays are not used for the treatment of alopecia areata and alopecia prematura for the very good reason that they are of no value for this purpose either in large or small doses. Cases that have apparently responded well to irradiation were, in all probability, spontaneous cures.

It is important to decide, if possible, if *x*-rays will cause a growth of hair under any circumstances whatsoever. Years ago, Allen, Bronson and many others were of the opinion that *x*-rays were capable of stimulating a growth of hair. In the past ten years there has been nothing in the literature dealing with this subject. The opinions of modern roentgenologists of experience, verbally expressed, is that *x*-rays do not stimulate the growth of hair.

The author has paid considerable attention to this subject. Occasionally one sees a growth of hair follow the cure of acne vulgaris with *x*-rays. In the author's experience this happens just as frequently in cases that have not been irradiated. A growth of hair has never been reported subsequent to *x*-ray treatment or radium treatment of other diseases, either with large or small doses. The growth of hair after depilation of the scalp hair for favus and ringworm is seldom if ever more luxuriant than before treatment. The author has never seen a growth of hair that could not be explained by causes other than irradiation. It is theoretically possible that a few fractional doses might stimulate a growth of hair. It is possible that such treatment might increase the growth of hair in patients who show a tendency to grow hair in abnormal situations (hypertrichosis). The possibility must be admitted, but it must be accepted as a doubtful possibility, not a probability. In any event there is no trustworthy, modern, corroborative evidence that either *x*-rays or radium are capable of stimulating a growth of hair, regardless of the circumstances.

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CHAPTER XXVII.

HYPERTRICHOSIS.[1]

To Freund should be given the credit of being the first to remove superfluous hair with x-rays. He depilated a nevus pilosus by this means. In fact this was the first case of any disease or condition to be treated with x-rays—the beginning of roentgen therapy. Later, Freund, together with Schiff, reported a series of cases of hypertrichosis of the face which they had cured with this new treatment. This report was followed by similar ones by Benedikt, Walsh, Ehrmann, Holzknecht, Kienböck, Noiré, Bordier and, in fact, by nearly all the early roentgenologists. In this country Pusey was the pioneer with Zeisler and Allen as close seconds.

The early workers were enthusaistic over the results obtained, but very soon it was discovered that a large percentage of the cases developed x-ray sequelæ—atrophy, telangiectasia, scarring and keratoses. In the beginning roentgenologists, while desiring to avoid a third-degree radiodermatitis, did not hesitate to evoke an erythema or even a second-degree reaction. In fact the very first case treated resulted in a serious radiodermatitis. Later, when it was found that even a mild radiodermatitis might leave disfiguring sequelæ and that it was difficult to avoid these mild reactions, enthusiasm waned.

Then came radiometric methods of measurement and improved technic. Again the work was undertaken with enthusiasm but this time with caution. The literature of the time is voluminous with reports of the excellent results obtained. However, optimism did not endure. Even with the most accurate technic accidents were common. It was soon ascertained that it was impossible to remove permanently superfluous hair from the face without the risk of at least visible wrinkling.

As far back as 1904 Allen, Schültz and many others condemned the method. Nevertheless there were many roentgenologists who continued to do the work, many of whom claimed consistently good results, while a few admitted occasional sequelæ.

Modern Opinion.—There are a few men who do not hesitate to treat hypertrichosis of the face with x-rays. They believe that it constitutes the method of election in many cases. Others believe that it is a risky method and that it should be used in only selected cases. A third group condemns the method outright. It will be profitable to review

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

in some detail the opinions of various modern dermatologists and roentgenologists.

Pusey states that: "In my experience practically satisfactory results can be gotten in about half of the cases; that is, the growth of hair can be reduced to an amount which is not unsightly by repeated series of exposures which are safe; in the other 50 per cent., however, this cannot be done. The results are so uncertain and the possibilities of harm are so great, that the treatment, in my opinion, should not be undertaken except in extreme cases, or with the full understanding that if the exposures are to be kept within the bounds of safety, improvement is altogether uncertain."

Ormsby: "After many years' observation of patients subjected to radiotherapy for removal of superfluous hair, the author has abandoned its use. While in some cases the result is satisfactory alike to physician and patient, the probability of future telangiectasis is so great as to be prohibitive of its continual employment."

Sutton does not recommend nor does he condemn the method. He calls attention to the dangers and the unsatisfactory results, but makes no comments. Hazen and Knowles are non-committal.

Hartzell suggests that *x*-rays may be used in cases in which the number of hairs is too great to be removed by electrolysis owing to the length of time required. He mentions the danger of the treatment. In another publication Hartzell states that "he had very grave doubts whether it was justifiable to employ the roentgen rays or similar remedies for the treatment of the class of lesions under discussion and for defects. The risk is too great and he did not think that we ought to assume any such risk."

Darier says that roentgen therapy cannot be recommended for this purpose.

Stelwagon regards the method as being uncertain and dangerous and it "should be limited, if used at all, to cases not otherwise manageable."

McEwen, in a long article on hypertrichosis, states that "the dosage required to permanently remove the hair is certain to damage the skin so seriously as to make the employment of *x*-rays or radium for this purpose distinctly ill-advised."

Jackson and McMurtry consider that *x*-ray treatment is inadvisable excepting in unusual cases and only in case the patient understands and accepts the risks.

It is obvious from the foregoing that the weight of dermatological opinion is against the use of irradiation for the removal of superfluous hair from the face. Roentgenologists may object that dermatologists for the most part have had too little personal experience with or that they are not sufficiently skilful in the use of *x*-rays. We will now see what roentgenologists have to say. Most roentgenologists refuse to treat cases of hypertrichosis. They are cognizant of the possibility of bad results and are unwilling to assume the risk.

Stern in 1912 reported 100 cases of hypertrichosis treated with

x-rays. Telangiectasia and atrophy were such common sequelæ that he discontinued the method. A few years later he again undertook the work, this time with filtered radiation. In 1918 he reported 74 cases treated in this manner. "The results accomplished in the 74 cases so far treated by this modified technic have been fairly satisfactory. The majority of cases have shown no sign of any permanent injury to the skin. Several have shown signs of telangiectasis and in some there is still a certain amount of hyperpigmentation persisting. I have not as yet seen any symptoms of skin atrophy developing in any of the cases treated. I realize that the time which has elapsed has not been sufficiently long to show all the damage that the *x*-rays may have produced, and that in course of time I may have reason to change my opinion about the ultimate results achieved in the cases treated."

Geyser gives a resumé of 200 cases of hypertrichosis of the face treated with *x*-rays. He admits a small percentage of bad results but insists that it is the elective treatment in cases that are not suitable for the electrolytic method.

Pfahler has reported numerous cases in which he was able to remove all or nearly all the hair without resulting disfigurement. He thinks that the method is indicated in selected cases. He is an advocate of filtered radiation. In a personal communication he admits that it is impossible to insure against more or less atrophy.

Speder, Gunsett, Chilaiditi and others advise the use of *x*-rays but insist on filtered radiation. Chilaiditi and Speder do not hesitate to effect an erythema. They believe that an erythema produced by filtered *x*-rays is harmless. This is a totally erroneous opinion. They deny telangiectasia but they admit that atrophy may occur in their cases later. Long before the work of these men, Kienböck, Bordier, and others had advised the use of filtered radiation in hypertrichosis and other cutaneous affections, but they avoided reactions when possible. Sendek and Novak, Rayner, Sairl and others have written on the *x*-ray treatment of hypertrichosis of the face. It has been impossible to find a single article written in the past ten years that does not admit that the method is risky. Few if any roentgenologists are willing to insure against visible wrinkling. One of the most optimistic of modern articles is from the pen of Meyer. He employs filtered radiation (4 mm. aluminium). An epilating dose is administered every six or eight weeks for a total of five treatments. The exposures are followed by local and general reaction. Meyer avers that there is no permanent injury. Max Joseph prefers *x*-rays to other methods in the treatment of hypertrichosis.

The above quotations are from articles written mostly by roentgenologists. In the text-books on roentgenology we find the following: Newcomet advises against the treatment. Schültz states that "it is now well-known to be an error, on cosmetic grounds, to treat this condition by means of *x*-rays. The falling out of the hair is at the present time a permanent condition if one irradiates until atrophy of

the skin is produced. The appearance of telangiectases on damaged skin is the rule on the face. Many a primary good results has later occasioned bitter disappointment. The disfigurement may make its appearance even years after the last treatment."

Tousey devotes two pages to this subject. It is doubtful if anyone would care to treat hypertrichosis with *x*-rays after reading his remarks and his case reports. Tousey states that it is necessary to effect a reaction in order to obtain a defluvium. Of course this is not true and it is decidedly inadvisable to go to this extreme.

In the most modern of all roentgenologic text-books Knox passes over the subject quickly. He favors filtered radiation and a preliminary dose of a strength sufficient to effect a defluvium. He does not mention the danger of atrophy, but states that if there has not been a reaction untoward effects need not be apprehended. The author's experience and opinion are not in accord with Knox's statements.

Heidingsfeld and Simpson have reported successful results in a few cases with radium treatment. Simpson states that "the quality of the skin from which the hair was removed is practically the same as that of normal skin." The word "practically" in the last sentence may mean much or little according to the imagination of the reader. Simpson also stated that "in certain types of localized hypertrichosis radium treatment seems to be the most effective method of relief." This sentence will be challenged by many. What is meant by "certain types of local hypertrichosis" and on what grounds does Simpson base the statement that "radium treatment seems to be the most effective method of relief?"

Object of Treatment.—Hypertrichosis (hirsuties; superfluous hair) is a growth of hair on parts that should be free of all but almost invisible lanugo hair. The etiology is unknown. Dermatologists look upon the condition as a cosmetic affection. That is, it is only of cosmetic importance. The object of treatment is to remove all the hair permanently with no difigurement or as little disfigurement as possible. As far as concerns hypertrichosis of the face of females it is the consensus of opinion among dermatologists that the best treatment is electrolysis. In the works quoted supra and in other writings, there is a dispute relative to the value of electrolysis. Some aver that the method is impracticable when there is a great deal of hair or when the hair is silky in texture. Many authors consider that such cases should be treated with *x*-rays. The author cannot agree with these opinions.

Comparison of Electrolysis and Irradiation.—It is the author's opinion that there are very few cases of hypertrichosis of the face that cannot be successfully treated by means of electrolysis. The work is tedious, time-consuming, and expensive. It requires skill on the part of the physician and patience on the part of both the physician and patient. If the number of hairs is enormous, a year of steady work may be required. If new hairs continue to grow, occasional treatments over a period of several or many years may be necessary. If the hair is light

in color and fine in consistence, a steady hand, a very fine needle and a good pair of eyes are essential. If the hair is coarse and especially if the roots are curved, it may be impossible to avoid some scarring. Very few dermatologists, for various reasons, acquire the necessary skill to obtain the best results with the electrolytic method. There are men and women, however, who are exceedingly expert in this work, who seldom cause scarring and who are not balked by seemingly impossible cases. The scarring that is bound to occur in some cases, even when the work is done by an expert, is not as disfiguring as the wrinkling that may result from *x*-rays and radium expertly administered. Assuming skilled operators, there is much less likelihood of permanent disfigurement (scarring and atrophy) subsequent to electrolysis than subsequent to irradiation. In the case of unskilled or unscrupulous operators, there is with electrolysis danger of unsightly scarring; with irradiation there is danger of scarring, atrophy, telangiectasia, keratoses and even more serious sequelæ.

It must be admitted that there are occasional cases in which it is absolutely impossible to obtain a satisfactory result with electrolysis. These patients have a widespread growth of downy hair. The individual hairs are almost invisible, but they are so numerous and so closely crowded as to be plainly visible and disfiguring when viewed ensemble. Unfortunately, it is just such a case that is most recalcitrant to *x*-rays because, paradoxical as it may seem, lanugo hair is more difficult to depilate with *x*-rays and radium than is coarse hair. This is not a real paradox. The explanation is that the hair bulb of coarse, rapidly growing hair, is composed of active cells, cells that are rapidly dividing. The contrary is true for lanugo hairs. It is a well-known fact that cells that are embryonic in type, and cells that are biologically or physiologically active, are more "radiosensitive" than are inactive cells.

As will be shown later it is possible with skill and judgment, to obtain excellent results with irradiation in cases that are not amenable to electrolysis. But irradiation is associated with danger of defects that are more disfiguring than the superfluous hair. Nothing of any value can be done for atrophy or wrinkling due to *x*-rays or radium. It cannot be even camouflaged. Skin can be kept free of hair with a razor or with depilatories if necessary. Certainly there is no sense in removing a defect that may be curable without disfigurement, or which at least can be kept hidden in various ways, for a defect that is permanent and which cannot be hidden.

So far we have only spoken of wrinkling and that is the only sequela that is likely to occur with modern technic, skill and judgment. However, there is also the possibility of occasional telangiectasia, which is very difficult and in many instances impossible to remove.

Time and expense are usually spoken of as factors in favor of irradiation and against electrolysis. Let us examine this question critically. Assume a girl with a large amount of fine, dark hair scattered over the

cheeks, chin and anterior neck. A good operator will, with the "electric needle" removed from 50 to 100 hairs in a sitting of one hour. It may require one or two treatments a week for a year to remove all the hair. In most cases from three to six months will suffice. If *x*-rays (or radium) are administered in a manner that is associated with the minimum amount of danger it will require about a year to effect a permanent alopecia, during which time a great many treatments are given. In acutal minutes or hours irradiation requires considerably more time than does electrolysis. In number of visits and expense there is little difference as a rule.

It is very disappointing and discouraging to a patient to learn that electrolysis will not prevent the growth of new hairs and that if new hairs continue to grow, treatment must be continued until this tendency spontaneously ceases. This news places the patient in a frame of mind that makes the permanent effect of irradiation very attractive —so attractive, indeed, that she is likely for the moment to belittle the risks associated with irradiation.

It is probably obvious to the reader that the author is not an advocate of *x*-ray or radium treatment for hypertrichosis of the face. If the dermatologist cannot or will not get the most out of electrolysis it is his duty to refer the patient to someone who will devote the necessary time and skill to the work.

Results Obtainable with X-rays.—It will interest the reader to know just what can be accomplished with modern technic. A combination of modern technic and skilled operator reduces the danger of radiodermatitis to a minimum and without radiodermatitis it is probable that there can be no telangiectasia, scarring or keratoses. But what is meant by a minimum? There is no exact answer. An amount of radiation sufficient to effect a defluvium of face hair, unfiltered, filtered, intensive or fractional, is very close to the amount required to evoke an erythema of the skin of the face. A certain percentage of first-degree reactions is followed by telangiectasia. Also, a certain percentage is followed by atrophy. These percentages are not known. They range somewhere between 3 and 10 per cent. It is possible to avoid even a mild first-degree reaction, but not with certainty. Mild to moderate first-degree reactions will occasionally occur in spite of the utmost care. Whether or not such reaction develops depends mostly on technic and judgment, but also upon mild grades of idiosyncrasy and other factors such as excessive exposure to sunlight, the application of irritating topical remedies, etc.

But let us assume for the sake of argument that an erythema can be avoided with certainty. What will be the result? In order to permanently remove hair from the face it is necessary to cause complete destruction of the hair bulbs and papillæ. Regardless of the method of application, when an amount of radiation sufficient to effect permanent atrophy of these parts, has been administered, there is bound to be more or less atrophy of elastic tissue, collagen, etc. Whether

the atrophy of the derma will be sufficient to effect visible wrinkling is impossible to say until a year or two after the last treatment. The amount of such atrophy depends both upon the technic and upon idiosyncrasy. The visible wrinkling depends partly upon personal peculiarities. For instance, a coarse skin will tolerate a greater amount of radiation without atrophy and a greater amount of atrophy without visible evidence of such atrophy, than will a fine-textured, fair skin.

The trouble is that various men have different ideas of good results and so do patients. The atrophy mentioned supra is not noticed in the axillæ and on various parts of the body, and it may not be noticed on the face when in repose. But when expressing the emotions, even when talking, the evidence of atrophy may become very noticeable, especially as the patient grows older. Whether the skin of the face is more prone to undergo atrophy than is the skin of other parts of the body, or whether atrophy of the face is more noticeable on account of location and muscular action, is unknown. It is probable that both factors play a rôle.

It is this type of atrophy that cannot be avoided. One cannot insure against this sequela regardless of the technic. It does not occur in all cases; the author cannot give figures; but it occurs too often to permit calling irradiation a safe or non-injurious treatment for hypertrichosis of the face.

In many instances it is impossible to remove all the hair without effecting a second-degree reaction. This is more common in the case of downy hair than in the case of coarse hair but it occurs with any type of hair. The author has seen hair growing in skin that is telangiectatic and atrophic.

Attitude Toward Patient.—There is hardly anything so detestable to women as a growth of hair on the face. Unless exceptionally philosophical and level headed, they are likely to suffer cruelly from a mental standpoint. The attitude of the physician should be sympathetic. It is a moral and scientific error to tell these patients that little if anything can be accomplished. Many dermatologists so detest doing electrolysis (and do the work so poorly) that the patient acquires a totally erroneous opinion of the method. These patients are exceedingly sensitive and easily discouraged and, like the sexual neurasthenic, provide food for the unscrupulous physician and charlatan. The attitude to take is one of interest and sympathy. The various methods should be outlined and their advantages and limitations described. If the advantages and safety of electrolysis are properly presented and the work is properly done, most patients will feel encouraged, confident and will accept such treatment in preference to irradiation.

Medico-legal Aspects.—Many physicians believe that if they explain the risks of x-rays and radium in the treatment of hypertrichosis of the face to the patient and the latter understands and accepts the risk, the physician cannot be held responsible for bad results. This is not true. There is nothing that can prevent the institution of a suit for mal-

practice if the patient desires to bring such suit. Not even a signed, witnessed and sworn statement, in which the patient states that she appreciates and accepts the risk, can prevent the suit.

The verdict rests almost entirely upon the question of negligence. The burden of proof is on the plaintiff (patient). The patient must prove that the defendant (physician) failed to employ the skill, judgment, care, technic, etc., as used under like circumstances by the average specialist in the same line, in the same community and epoch. The fact that the plaintiff understood and assumed the risk does not negative negligence on the part of the defendant. If the defending physician used a method of treatment that has been and is advocated by specialists in good standing and his judgment and technic were in accordance with the required standards of his profession, *i. e.*, absence of negligence, then he is immune insofar as concerns damages.

The majority of dermatologists and roentgenologists are either opposed to the treatment of facial hypertrichosis with *x*-rays or radium or they reserve such treatment for exceptional cases. On the other hand, there are many experienced men of the very best standing who advocate the method. This minority opinion is a protection against damages providing the patient clearly understands the risk before submitting to the treatment. It is advisable to obtain a written, witnessed and signed statement to this effect in order to prevent perjury or "forgetfulness."

Hypertrichosis patients are exceedingly friendly when seeking relief, and are ready to "grasp at a straw," but many of them become exceedingly bitter and revengeful if they develop *x*-ray sequelæ. *X*-ray treatment appeals to the patient because there is no temporary disfigurement, no pain nor discomfort, because there is economy of time and particularly because the effect is permanent. The method is so attractive and the appeal is so great that the patient is likely to belittle the statements made relative to the danger of *x*-ray sequelæ. They fail to visualize the result. At this time they are perfectly willing, they say, to have a little wrinkling substituted for the repulsive hair. But a year or two later, long after the hair has disappeared and wrinkling has occurred, they realize they have a defect that cannot even be hidden. They forget their original appearance and anguish. They feel that they were deceived and they seek revenge.

The physician must be exceedingly careful not to allow the pleadings of a patient before or during treatment to interfere with his judgment. Furthermore, if he undertakes the treatment he should be absolutely certain that the patient is made to realize the possible end-results. He should never take it for granted that the patient is a "good sport" and will overlook an accident or unavoidable sequelæ. Finally, the physician should understand thoroughly that while absence of proof of negligence will make it difficult if not impossible for the patient to collect damages, there is nothing that can prevent the institution of a malpractice suit. For further medico-legal details the reader is referred to the medico-legal chapter.

Hypertrichosis of the Body.—There is less risk of bad results when treating hypertrichosis of the body with *x*-rays or radium than when treating the same condition on the face. The chances of radiodermatitis with subsequent sequelæ are about the same, but visible wrinkling without antecedent reaction is not as frequent or if it is as frequent it is not so noticeable. Finally, if telangiectasia should occur it can be covered with clothing.

Removal of Hair in Plastic Surgery.—During the war, especially in English hospitals, it was necessary to close large gunshot wounds of the face with inverted flaps from the neck. Before doing this, in order not to have the hair grow in the mouth, it was necessary to permanently destroy the hair follicles. Cole and Knox record cases where the results of irradiation used for this novel purpose were most excellent. Irradiation in such cases is essential.

Technic (X-rays).—*Intensive Technic.*—Various roentgenologists use different methods of applying *x*-rays for this purpose. Most of them use the intensive method. That is, they apply enough radiation at one sitting to effect defluvium. In the opinion of the author this is the most dangerous of all methods, particularly when attempting to remove hair from the face of a woman. It is difficult, almost impossible, with filtered or unfiltered radiation, to effect a complete or even a partial defluvium of face hair with one treatment without causing an erythema. An erythema (mild first-degree reaction) must, of course, be avoided if possible. As a rule it requires as much radiation to depilate face hair as is required for defluvium of scalp hair. In many instances a greater quantity is required. The epilating dose (H1 or H1¼ S. D. unfiltered or from H1¾ to H2¼ S. D. filtered) will effect defluvium of scalp hair without effecting a skin reaction, but this amount of radiation applied to the face is very likely to provoke a reaction.

After depilation, unless the treatment is continued, the hair will return in from one to three months. It is customary, therefore, to repeat the treatment about every six weeks with slightly smaller doses for a total of from four to six treatments. Such treatment will usually suffice for total and permanent destruction of the hair follicles.

Fractional and Semi-intensive Technic.—By applying a fractional dose (H¼ S. D.) once a week the hair will eventually fall out and cease to return. This will require in the neighborhood of eight months to a year or more. There will be no reaction but, of course, there is very likely to be atrophy. The fractional method is hardly ever employed for this purpose.

A better method is to administer H¼ S. D., unfiltered, every five days for a total of H1. If, after waiting three weeks the hair has not fallen and there has been no reaction, the same doses are administered at intervals of four days; and later, if necessary, at intervals of three days. In this manner it will be usually possible to obtain a defluvium without the slightest sign of reaction. After the hair is out it is neces-

sary to give H¼ weekly, H½ bimonthly, or H¾ S. D., unfiltered, monthly for from six to eight months or even a year in order to prevent a return of hair.

Face.—The *x*-rays should be applied to the face by the four-exposure method as described by Kienböck. A detailed description of this method will be found under the heading of Tinea Barbæ.

Axillæ.—The method of applying *x*-rays to the axillæ will be found under the heading of Hyperidrosis.

Trunk.—It is a difficult matter to obtain uniform dosage over extensive and irregular surfaces. The author has treated men who had a very heavy growth of coarse black hair scattered over the chest, shoulders, arms, and upper back. In such instances multiple exposures are made as follows: The tube is centered over the anterior axillary fold of first one side and then the other side on about a level with the nipple; the oblique rays are allowed to overlap upon the chest. The same procedure is followed for the upper back. Finally, an exposure is made to the external aspect of each arm near the shoulder, the incidence being at right angles to the exposures for the chest and back. All non-hairy parts are adequately protected with lead foil or other suitable material.

Extremities.—As a rule the growth of hair is limited to the extensor and lateral aspects of the forearms and, perhaps the backs of the hands. To equalize the dose over such a large and convex surface requires six exposures for each forearm. With the palm of the hand resting on the table, the anode is centered first over the elbow and then over the back of the hand. The distance between the two positions should be about nine inches. The same procedure is then followed for each lateral surface, providing, of course, that the hypertrichosis involves these surfaces. Only the non-hairy parts are protected. A similar method is used for the legs.

Danger Signs.—At each visit the skin should be carefully tested for evidence of a reaction—even for premonitory symptoms of a reaction. Skin that is nearly ready to show visible signs of mild radiodermatitis is usually irritable. It will flush readily, even upon change of posture or slight pressure. It reddens quickly under the influence of heat or even under emotional excitement. It is irritable when exposed to wind or sunlight. A very good way to determine if one is close to the danger point is to note the erythema produced by slapping or by the application of a folded towel wet with hot water, as compared with the effect produced on neighboring unexposed skin.

At the slightest evidence of reaction or even in the presence of marked premonitory symptoms, the exposures should be discontinued temporarily.

The patient should be cautioned against doing anything that might enhance the effect of the *x*-rays, such as exposure to the sun and wind, application of stimulating and irritating topical remedies, etc.

Filtration.—The author is not convinced that filtered x-rays are better than unfiltered x-rays for the treatment of hypertrichosis. Certainly there is no harm in using a filter and there may be an advantage. The possible advantages of filtered radiation are as follows:

1. There seems to be a little greater latitude between the amount necessary to effect a defluvium and the amount necessary to provoke an erythema.
2. There is a smaller proportionate absorption of radiation in the tissue between the niveau of the epidermis and the hair papillæ.

These points are discussed in detail in the chapter on General Therapeutic considerations and need not be repeated here. It is well to emphasize, however, that it is necessary to completely and permanently destroy the hair papillæ. As stated before in this chapter, when an amount of radiation, even heavily filtered radiation, sufficient to destroy the follicles has been administered, there will be a certain amount of atrophy of other parts of the true skin. The shrinking due to loss of hair follicles, atrophy of other appendages and of collagen and elastic tissue, may be sufficient to produce visible puckering or wrinkling, especially on motion.

The author cannot deny that under exactly similar circumstances there is less danger of visible wrinkling with filtered radiation. He has not noticed any particular difference but he respects the opinion of others who after long experience aver that there is a difference. In any event it is important to note that filtered radiation does not insure against wrinkling. It is important, also, to realize that an erythema caused by filtered radiation may be followed by the same sequelæ as those encountered subsequent to reactions caused by unfiltered radiation.

Radium.—In a general sense what has been written in this chapter relative to the use of x-rays in the treatment of hypertrichosis applies to radium. For extensive surfaces radium is inconvenient. The hair bulbs and papillæ are a little too deep to be treated successfully with "soft" beta rays. Therefore it is preferable to utilize only the "hard" beta rays or the gamma rays. For further details the reader is referred to the chapters on Radium Technic and General Therapeutic Considerations.

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CHAPTER XXVIII.

DISEASES OF THE HEMATOPOIETIC SYSTEM.[1]

THE diseases that will be discussed in this chapter are:

1. Granuloma Fungoides.
2. Leukemia Cutis.
3. Lymphogranulomatosis Cutis.
4. Hodgkin's Disease.

GRANULOMA FUNGOIDES (MYCOSIS FUNGOIDES).

Schültz (Germany, 1902) was the first to employ x-rays for the treatment of mycosis fungoides. Belot (France), Jamieson (England) and Allen (United States), were the first to use x-rays for this purpose in their respective countries.

These initial records were followed immediately by reports by Walker and Brooks, Stainer, Riehl, Marsh, Hyde, Montgomery and Ormsby, Carrier and Pusey. Since these early reports the literature has become voluminous.

Clinical Features.—A controversy exists today with respect to granuloma fungoides, not only in its clinical but also in its histopathological features. Some dermatologists of experience and repute often show a tendency to include under the entity known as granuloma fungoides, certain generalized and universal erythrodermias, sometimes associated with lichenification, not accompanied by any characteristic blood changes, and probably related to the so-called "aleukemic" leukemides, to pityriasis of Hebra, or to dermatitis exfoliativa. These generalized erythrodermias certainly do not respond to roentgen therapy as does granuloma fungoides. As a rule the lichenification, if it exists, will subside under roentgen therapy; but complete retrogression, as obtains so frequently in granuloma fungoides, is the exception rather than the rule.

The roentgenologist should be acquainted with the behavior of granuloma fungoides when irradiated and when not irradiated. The reader is advised to study the affection in any standard text-book on dermatology. Only the essential features will be mentioned here.

The disease begins usually with an eruption that may resemble eczema, psoriasis, parapsoriasis, or neurodermatitis. This is the prefungoid stage. The eruption is almost always pruritic, the itching as a rule being intense. The individual lesions consist of dusky-red, scaly patches of various sizes. During the evolution of the eruption

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

old lesions may spontaneously involute, and there may be periods of quiescence. More commonly new lesions continue to appear until the eruption is generalized. The prefungoid stage may be of several years' duration, it may endure for only a few weeks or months, or it may be entirely absent. In the last instance the disease begins with infiltrated plaques, nodules or tumors.

The fungoid stage is represented by nodules and tumors that range in size from a pea to a cocoanut. The lesions may be firm, smooth tumors or they may ulcerate and form large fungating masses. The lymphatic glands enlarge, the patient becomes cachectic and death follows from septicemia, toxemia, exhaustion, or death may be due to visceral involvement. Tumors occasionally spontaneously involute, either by suppuration or by resolution and absorption, but new lesions continue to develop.

FIG. 145.—Granuloma fungoides (prefungoid stage) before treatment.

FIG. 146.—Same patient shown in Fig. 145, after generalized roentgenization.

The prognosis is practically hopeless, excepting as to prolongation of life by x-ray and radium treatment. The patient may live from a few months to fifteen years, the average being from two to four years.

After the development of tumors the patient usually succumbs in a few months or at most in two or three years. There have been but 3 cases of permanent cure on record. One cure followed an attack of erysipelas; 2 others followed the administration of arsenic (Bazin, Köbner, Geber).

Effect of X-rays and Radium on Prognosis.—The author has failed to find a single report of a permanent cure of granuloma fungoides with *x*-rays or radium. The early literature contains a number of reports of clinical cures without recurrence for a year or two. Sequeira (1914), in an excellent article on granuloma fungoides in which he reviewed the literature, failed to find a single case of the disease that had been permanently cured with *x*-rays. The discussion following the paper was brilliant. All the speakers (Pringle, Malcolm Morris, McDonagh, Galloway, Stowers, Abraham, Whitfield, Pernet, Graham Little, MacLeod and Dore) were of the opinion that *x*-rays could not be depended upon to permanently eradicate the disease, although they might do so rarely. Whitfield reported 1 case where there had been no recurrence for five years and Sequeira told of a patient who had been free of clinical evidence of the disease for four years. Bisserié obtained 5 cures out of 6 cases; in 1 case there was a recurrence; the period of observation was fifteen months.


Fig. 147.—Granuloma fungoides (prefungoid stage) before treatment.


Fig. 148.—Same patient shown in Fig. 147, after generalized roentgenization.

A review of text-books and articles shows that it is the cons of modern opinion that x-rays and radium are superior to any

Fig. 149.—Granuloma fungoides, fungoid stage, before treatment.

Fig. 150.—Same patient shown in Fig. 149, after generalized roentgenization

known therapeutic agent or combination of such agents for the treatment of granuloma fungoides. Patients may be kept alive and in comfort for years. Such patients, however, eventually succumb to the disease if they have not died of some intercurrent affection in the meantime.

Effect on Symptomatology.—The effect of irradiation on the cutaneous lesions of granuloma fungoides is spectacular—dramatic. It is possible (but not advisable) to cause complete involution of the largest tumors or most extensive plaques with one treatment. Patients who are literally covered with lesions, who are suffering intensely from pain and itching, who are in exceedingly poor general health, and who have failed to obtain relief with other remedies, can, in the majority of instances, be clinically cured by the proper use of *x*-rays. What a pity that the relief is not permanent! The author has treated 30 cases of granuloma fungoides with *x*-rays and radium. The following description of the action of these agents on this disease is based on personal experience.

To determine the exact value of irradiation in the treatment of granuloma fungoides is not an easy matter. The result seems to depend partly upon technic and judgment and partly upon the disease itself. As we shall see later there is evidence to support the opinion that the symptoms can be made worse, the disease can be made more malignant, complications can be effected and death can be hastened by improper technic. But first let us assume proper technic and confine our attention to the behavior of different clinical types of the affection.

Cases are encountered in which the *x*-rays seem to be of little benefit. New lesions develop as fast or faster than the old ones disappear. In a few weeks or months the treatment ceases to be beneficial and the patient succumbs. Fortunately such cases are in the minority. Even in these malignant cases irradiation is of value in temporarily lessening the itching. Rarely, *x*-rays have no effect whatsoever.

It is rather a common phenomenon to observe patients who do fairly well under irradiation but who are never entirely relieved. These patients, like the former type, usually have a generalized eruption consisting of erythematous patches, infiltrated plaques and, perhaps, tumor formation. Itching is greatly relieved and may be entirely arrested. The lesions involute in a few weeks but new lesions continue to appear. By more or less constant, carefully conducted irradiation, these patients can be kept comfortable most of the time for several years. Sooner or later, usually in from two to five years, the treatment loses its effect. New lesions develop even in locations that are being irradiated. Both new and old lesions fail to be benefited; even itching is no longer relieved. After *x*-rays cease to be of service these patients die as a rule in a few months.

There is a third group of cases, the most common of all, in which

the patients, after a course of x-ray treatment, remain asymptomatic for varying lengths of time—from a few months to a year or two. The recurrences are readily amenable to irradiation and the patients remain comfortable for several to many years. Some patients require several courses of treatment each year while others require only one or a few treatments each year or every two or three years. Sooner or later, however, the disease fails to yield to the treatment and the patient succumbs.

Usually it is impossible to determine the prognosis the first time the patient is examined. But after watching the effect of roentgenization for a few weeks or months it becomes possible to place the case in one of the three groups outlined above and hence the prognosis is determined. Generalized eruptions of either the prefungoid stage or the fungoid stage, in apparently exceedingly severe cases, will often clear up and the disease will remain under control for many years. The same is often true even in cases when the fungoid stage is not preceded by a prefungoid eruption. Conversely, one meets with apparently mild cases that very soon become exceedingly recalcitrant. It is this last type, together with phenomena that will be described later, that has led many to believe that irradiation is the cause of the change from benign to malignant type. As will be seen later, injudicious irradiation may effect this undesirable result, but the same thing is noted, not only when the technic is proper, but even when x-rays or radium are not used.

FIG. 151. — Granuloma fungoides. Vegetating lesions on tongue before treatment.

FIG. 152.—Same patient shown in Fig. 151, after one subintensive x-ray treatment.

ILLUSTRATIVE CASE REPORTS.

CASE 10.—Mr. J. H. D., fifty-five years of age. The disease first became manifest fourteen years ago. For the first few years the eruption resembled eczema. Eleven years ago Howard Fox successfully treated the patient with *x*-rays for a generalized prefungoid eruption. The eruption returned in a few months and again became generalized. For a period of two or three years the disease was held in abeyance with *x*-rays by Dr. Fordyce. The patient then fell into the hands of the author. For several years there were no erythematous patches but a few nodules would develop two or three times a year. These lesions disappeared promptly when irradiated. For the past four years it has not been necessary for the patient to receive *x*-ray treatment more than twice yearly and during one entire year there were no lesions.

CASE 11.—Miss A. B., thirty-five years of age. The patient developed a few nodules, the first evidence of her trouble, in 1915—mycosis fungoides d'emblée of the French school. The lesions disappeared as a result of three fractional *x*-ray treatments at weekly intervals. One year later there was a recurrence, the lesions disappearing promptly when irradiated. There were no lesions in 1917 and 1918. In 1919 there were two outbreaks the first consisting of nodules and the second, eight months later, consisting of two erythematous plaques and a few nodules, all of which involuted under a few fractional treatments. The last attack required almost double the amount of treatment necessitated by the earlier recurrences. At the present writing (August, 1920) the patient has been free of symptoms for eight months.

These two patients are the most favorable cases ever seen by the author. Most patients require several courses of treatment each year.

CASE 12.—Mrs. B. A., thirty-three years of age. This patient had had an eruption for two years before *x*-ray treatment was instituted. When treatment was begun the eruption was generalized and consisted of slightly infiltrated scaly and intensely pruritic plaques. There have never been any tumors or nodules. In spite of carefully administered *x*-ray treatment the patient has not been entirely free of lesions during a period of six years. Most of the time the eruption has been kept under control, the patient requiring weekly treatments for new lesions in circumscribed areas. Occasionally the disease would remain quiescent for a month or two, but most of the time new lesions were constantly developing. The best that could be done in this case was to keep the patient comfortable and almost free of lesions.

The behavior of the disease under roentgenization as outlined in Case 12 is common. Such patients can be kept comfortable for periods ranging from a few to many years. Case 13 represents a slightly different type where the results are better.

CASE 13.—Mrs. M. M., forty years of age. Duration of affection before roentgenization, one year. The eruption was generalized and consisted of prefungoid lesions. The eruption disappeared in a few weeks under *x*-ray treatment and the patient remained asymptomatic for six months, when there was a rapid development of new lesions. This patient has been under observation for eight years. She has a recurrence once or twice a year; the eruption always disappears promptly when irradiated.

The next patient illustrates a common termination of even favorable cases.

CASE 14.—Mr. G. W. The history of the eruption and its action when radiated were similar to Case 13. At the end of four years prefungoid lesions eveloped faster than they could be made to disappear. A few months later -rays ceased to prove efficacious, the eruption became universal, tumors and nlargement of lymphatic glands developed, and the patient became cachectic nd died.

The remaining case reports illustrate the more unfavorable types.

Case 15.—Mr. J. A. C. The prefungoid stage had been present for five years. When first seen by the writer, there was a generalized, prefungoid-type of eruption with numerous tumors scattered over the body. The tumors ranged in size from a pea to a walnut. The patient had been given two or three *x*-ray treatments each week over a period of four months with considerable improvement. After four months of almost daily treatment the patient was free of skin manifestations but his general health was not very good. He returned in six months and stated that new lesions had been constantly developing and that they had not been influenced favorably by *x*-ray treatment received in another city. Carefully administered treatment kept the patient comfortable and fairly free of lesions for a few months; then *x*-rays ceased to have any effect at all. The patient died two months after cessation of *x*-ray treatment.

Case 16.—Mrs. G. B. A Jewish woman, thirty-eight years of age, exhibited a generalized eruption consisting of pruritic, infiltrated plaques and numerous painful tumors ranging in size from a pea to a hickory nut. The duration of the disease was three years, during which time the patient had suffered severely, especially with the itching. *X*-rays had not been administered. Under the influence of irradiation itching was temporarily relieved and some of the lesions disappeared. In less than a year, however, *x*-rays ceased to be of benefit and the patient died.

Case 17.—Mr. A. C. D. This patient had had mild prefungoid symptoms for an indefinite period. He had never received *x*-ray treatment. Suddenly there developed numerous, very itchy plaques which were scattered generally over the body. The eruption disappeared under *x*-ray treatment. Three months later the patient exhibited markedly enlarged axillary, inguinal and cervical glands, and a few infiltrated plaques. Both the adenitis and plaques involuted slowly under *x*-ray treatment. The patient was asymptomatic for four months. There was then a return of the adenitis and skin manifestations, the eruption consisting of infiltrated plaques and tumors and nodules. *X*-rays were no longer efficacious and the patient succumbed.

Possible Injurious Results of Irradiation.—On several occasions it has been alleged that, as a result of roentgen therapy, the disease, which had been previously relatively benign, assumed a malignant type and death resulted in a few months. White and Burns report a case which began with red, scaly patches in 1902; tumors and ulcers began to appear in 1904. While the eruption was widespread, nevertheless the patient was in good general health up to June 29, 1905, when the *x*-rays were first applied. The radiation was first administered tri-weekly in very moderate doses to a group of ulcerated lesions in the pubic region. The temperature which had been practically normal, began to rise on July 3 and reached 103° on the 8th. It then fell rapidly and reached normal on the 11th, only to rise again to 104° on the 13th. The temperature was again normal on the 15th. During this period the treatment had been confined to the only ulcerated lesions, which were in the pubic region. From July 15 to August 22 the treatment was applied to all parts of the body. The temperature during this period was as follows: It was practically normal until August 4 when there was a sudden rise to 102° for one day. It was again normal until the 22d when there was a sudden rise to 105°.

The evening temperature then ranged from 103° to 105° until September 7 when the patient died. There was a gradual improvement in the eruption which entirely disappeared before death. Two blood counts were made: August 18: white cells, 16,000; neutrophiles, 60 per cent.; small lymphocytes, 29 per cent.; large lymphocytes, 8 per cent.; eosinophiles, 2.5 per cent.; basophiles, 0.5 per cent. September 6: white cells, 36,000; neutrophiles, 70 per cent.; small lymphocytes, 23 per cent.; large lymphocytes, 6.5 per cent.; eosinophiles, 0.5 per cent. The autopsy and postmortem bacteriological findings revealed a streptococcus septicemia. White considered that death was due to toxemia resulting from the too rapid involution of the lesions under the influence of the *x*-rays.

In analyzing this case there are several points to be considered. In the first place the tumor stage of the disease was manifested within two years so that it was not a particularly benign type. It required two months of steady treatment to overcome the lesions, which were scattered over the entire body. The *x*-ray treatment was given by Dodd who stated that the individual exposures were very moderate in strength, that they were given about every second day and that only small portions of the body surface were treated at a time. In the light of modern experience the length of time allowed for the disappearance of all the lesions was a little short and the treatment, perhaps, was too energetic although, as will be seen later, there are no substantial grounds for criticizing this feature of this particular case.

The blood counts are interesting because it might be claimed that the *x*-rays lowered the lymphocytic elements and therefore reduced resistance. In this case the total lymphocytic count after two months of treatment was 37 per cent.—perhaps a little above normal. Just before death the lymphocytes fell to 29 per cent.—perhaps a little below normal. At the same time the total count had increased from 16,000 to 36,000 with a gain of 10 per cent. in the neutrophiles. The blood picture is rather more suggestive of septicemia than of toxemia. As a comparison the author had a case of advanced granuloma fungoides, the lesions of which consisted of erythematous, slightly infiltrated plaques, nodules and fungating and ulcerating tumors. The individual lesions were somewhat recalcitrant and for a few months new lesions appeared almost as fast as the old ones disappeared. It was necessary to treat the entire body and daily exposures, gradually increased in amount, were given over a period of seven months before the patient was symptomatically cured. At one time he was receiving as much as H2 S. D. unfiltered in divided doses, in one month, over the entire body surface. In spite of this intensive treatment and the enormous number of lesions that underwent involution, the patient never presented the alarming symptoms as seen in White's case and the blood count at the end of the *x*-ray treatment was as follows: Total white cells, 7200; polymorphonuclears, 78 per cent.; lymphocytes, 22 per cent.

Now to return to White's case. The febrile reaction, also, was as suggestive of septicemia as of toxemia. Shortly after the institution of *x*-ray treatment and while the *x*-rays were being applied to one ulcerative lesion, the temperature reached 102°. Then it returned to normal in spite of the fact that the treatment was continued and that the ulcer was still unhealed. Then, during the next two months, with the exception of two upward excursions of short duration, and while the *x*-rays were being applied to the entire body, the temperature remained practically normal. It then suddenly assumed a septic curve and a few days later the patient died. Finally the autopsy revealed that there was no internal dissemination of the disease and the macroscopic and microscopic evidence was that of streptococcus septicemia. While it is possible that the death of White's patient was due to toxemia the evidence warranted the pertinent remarks of Pollitzer during the discussion of White's paper: "Dr. Pollitzer inquired why the death of Dr. White's patient had been ascribed to toxemia? The autopsy findings showed streptococci in the blood, and in view of the quite frequent occurrence of death in the course of mycosis fungoides from septic infection from without, derived through the skin lesions, the speaker said that he wished to ask why Dr. White presented his case as one of toxemia rather than one of simple streptococcus septicemia?"

Roman reports two interesting examples of granuloma fungoides, in which *x*-rays were employed. The first patient had had eczema-like lesions off and on for ten years. These would either disappear spontaneously or yield to ointments. Finally nodular masses and ulcerating lesions developed which, after resisting ordinary treatment for a year, disappeared as a result of five *x*-ray exposures. Six months later a polymorphous eruption, including ulcerating tumors, suddenly appeared. *X*-ray treatment was given daily, only one small section of the body being exposed on any one day. It was necessary to discontinue the use of the *x*-rays over long intervals on account of febrile reactions which Roman states were due to both *x*-rays and the ulcerating tumors. While a few lesions disappeared under the influence of the *x*-rays, most of them continued to ulcerate and the patient soon died. The blood count before the institution of *x*-ray treatment showed a total white cell count of 9500. The differential count gave: Polymorphonuclears, 68.5 per cent.; small lymphocytes, 12 per cent.; large lymphocytes, 17 per cent.; transitionals, 2 per cent.; eosinophiles, 0.5 per cent. Just before death there was a marked anemia and the total white count increased to 27,000. The differential count was not given but the increase consisted mainly of polymorphonuclears. The autopsy revealed microscopical and gross changes in the viscera suggestive of granuloma fungoides.

In analyzing this case one seems hardly warranted in placing any blame upon the *x*-rays. The doses were mild or moderate, there was

very little involution of the lesions and there was a great deal of ulceration and sloughing. The febrile reactions were very probably the result of septic absorption and death was most likely due to the disease itself. The author feels that the disease in this particular instance was malignant and its course was practically uninfluenced by the *x*-rays.

The second case was of nine years' duration. The eruption consisted mostly of erythematous, slightly infiltrated plaques, a few eroded lesions and non-ulcerating tumors. Soon after the institution of *x*-ray treatment there was a febrile reaction and an erythematous eruption which began as pinhead to silver-dollar sized, discrete macules which soon became confluent. The eruption was generalized. It disappeared in about two weeks, leaving a pigmented, slightly scaly skin. The *x*-ray treatment, which had been discontinued at the onset of the febrile reaction, was again resumed; the patient made an uneventful recovery, the lesions of mycosis fungoides disappearing and there were no more febrile or skin reactions. Blood counts were made at intervals and were found to be practically normal.

In commenting upon this case Roman states: "The striking features . . . are the febrile turn and the erythema-like eruption, which could not be accounted for by repeated examinations of the internal organs and certainly do not belong to the picture of granuloma fungoides. It seems that an explanation of these must be sought in some form of roentgen toxemia. *X*-ray intoxications are not at all rare . . . it is pretty well known that every living cell which absorbs roentgen rays undergoes a pathological change as a result of a chemical dissociation occurring in its substance analogous to the process in the photographic plate. When the process becomes sufficiently intense the pathological changes manifest themselves microscopically in a degeneration of the cell as evidenced by a granular breaking down of the protoplasm, vacuolization of the nucleus and loss of staining quality of the same. Gradually this leads to a total disappearance of the cell, the products naturally being absorbed. It is, therefore, not unreasonable to suppose that when the absorbed material is in great excess as, for instance, in cases with large sensitive growths and very frequent exposures, especially in a susceptible individual, these absorbed products acting like toxins should produce a reaction of considerable severity."

In analyzing this case there is one feature that must not be overlooked. "Six years ago there occurred a violent rash which, among other things, was treated with *x*-rays and which soon subsided only to return in a very short time." Just what was meant by "violent rash" is not plain. It may have been an acute, generalized, erythematous eruption similar to the later attack or it may have been the rather sudden outbreak of prefungoid lesions of granuloma fungoides.

As Roman says, the peculiar eruption following the use of the *x*-rays in his second case is not a part of the picture of granuloma

fungoides, but can it be said with certainty that the eruption was due, indirectly, to the *x*-rays? The patient received only a few mild applications, and the lesions did not disappear quickly, circumstances that would militate against the theory of the too sudden absorption of large amounts of toxic material from the involuting lesions.

In this connection, it is profitable to consider the effect of the *x*-rays on other generalized affections which are often treated with *x*-rays psoriasis, eczema, dermatitis exfoliativa, leukemia, etc. The author has treated a large number of cases of generalized psoriasis, where it was necessary to apply the rays to the entire body and in which the lesions underwent fairly rapid involution, yet a sudden cutaneous eruption associated with febrile disturbance has seldom occurred. The same can be said regarding splenic and splenomyelogenous leukemia, when *x*-rays have been extensively and rather intensively applied over long periods and when the reduction in lymphocytic elements has been fairly rapid.

However, there is hardly any doubt but that the too intensive irradiation of pathological and even of normal tissue may effect symptoms of toxemia. In some instances it is possible that even small doses might cause more or less toxemia. In the literature, especially that prior to 1910, there are numerous references to toxic manifestations caused by *x*-rays. The fact that we now seldom encounter such symptoms, because of improved technic and cautious and conservative administration, would seem to indicate that many of the toxic reactions of former years were really caused by the treatment. Briefly the early references are as follows:

Holzknecht observed febrile reactions and a scarlatiniform dermatitis in several patients afflicted with different diseases. The eruption lasted only a week or two and was followed by exfoliation of the epidermis. He also noted instances of a pruritic, maculo-papular eruption, which was thought to be the result of roentgenization. Kienböck mentions three similar cases observed by him. Engle writes of a case of leukemia which, after receiving two hundred and eighty minutes of total irradiation suddenly developed a severe febrile reaction with symptoms of toxemia. Death occurred in a few days. Fricke noted, in a case of leukemia, a febrile reaction, toxic symptoms, and an extensive cutaneous eruption of a seborrheic dermatitis or psoriatic type. Schaumann observed a generalized, itchy, papular eruption following intensive roentgenization of the spleen in a case of splenic leukemia. Edwards, while not giving specific details, is convinced that death often results from toxemia as a result of the *x*-ray treatment of internal cancer. Sterne reports a case of splenic leukemia in which there developed a toxemia with symptoms simulating an acute sepsis. Even the microscopic blood findings indicated a septicemia. Pusey mentions a rash and symptoms of toxemia occurring in a case of lymphadenoma after fifteen exposures. Allen has observed cutaneous eruptions, febrile reactions and toxic symp-

toms following the disintegration of large tumor masses under the influence of the *x*-rays. Gibson calls attention to the fact that in all deep-seated, extensive tumors the *x*-rays may cause rapid disintegration and the dissolved material being thrown into the circulation in large amounts, produces a condition of sepsis. Nielsen, Dock, Haret, Linser, Franklin and Lyle are all quoted by White and Burns as having observed toxic symptoms following the use of the *x*-rays in deep-seated cancer, leukemia, etc. Most of these authors ascribed the toxemia to the *x*-rays, but Dock states that toxic symptoms occur so frequently in leukemia that it is impossible to tell how much influence the radiation has in producing such manifestations. Linser found that *x*-rays destroyed the leukocytes, especially the circulating lymphocytes. Also, a leukotoxin was produced and when a serum containing this substance was injected into an animal a destruction of leukocytes followed. For further details relative to the action of *x*-rays and radium on the lymphocytes see Chapter XIV. Pancoast in his many articles on the *x*-ray treatment of leukemia has repeatedly called attention to the advisability of employing small oft-repeated doses.

The author has seen two cases of granuloma fungoides in which there were phenomena suggesting toxemia during a course of *x*-ray treatment. One case was very similar to Roman's second patient. The patient had received daily irradiation for a period of four months. The treatments were so arranged that the entire body surface received H½ S. D., unfiltered, the first month, H1 the second and third months, and H2 the fourth month. The lesions, which consisted of erythematous plaques, nodules and ulcerating tumors, underwent rather slow involution and new lesions developed as fast as the older ones disappeared. Toward the end of the fourth month there gradually appeared an eruption of erythematous, non-infiltrated macules and plaques. The individual lesions ranged in size from a pinhead to an adult palm. They developed first on the chest and abdomen and spread rapidly all over the trunk and extremities. The lesions then coalesced to form a fairly generalized eruption. The lesions of granuloma fungoides became more pronouncedly red and two of the plaques showed the presence of bullæ, but there was no visible change in the tumors. There was edema of both legs, a slight elevation in the temperature and a trace of albumin in the urine. There was no prostration. Irradiation was discontinued and in three weeks the eruption had disappeared leaving a temporary yellowish-brown stain and an exfoliation. Only a few new mycosis lesions were now developing and the old lesions were disappearing. The *x*-ray treatment was recommenced and at the end of the sixth month the patient was free of lesions, in good general health, and left for his home in Cuba. A few months later plaques and tumors again developed. At first they were improved by *x*-ray treatment, but very soon the *x*-rays ceased to have any effect and the patient died.

[illegible]

[illegible] It is quite possible [illegible] with an analogous [illegible] the x-rays. The [illegible] consider the evidence [illegible] of these toxemic [illegible] granuloma fungoides will have not [illegible] be remembered, also, that hundreds [illegible] been treated in this manner without the [illegible] symptoms. Granuloma fungoides is a very peculiar disease. In any one of the three stages (erythematous, infiltrative, fungating) there may be a spontaneous and rather rapid involution of the lesions; patients with ulcerative lesions often develop septicemia and cachexia; metastases into the internal organs occasionally take place. Therefore, one is not warranted in blaming these phenomena on the x-rays, especially when the evidence is so meager. It is even possible that the peculiar cutaneous manifestations in Roman's patient and in one of the author's patients, might have occurred if the x-rays had not been employed. It is well to bear in mind, however, that there is reason to believe that the x-rays, under certain circumstances, can produce more or less grave toxic disturbances and that the too intensive roentgenization of the lesions of granuloma fungoides may bring about undesirable results.

Technic (X-rays). Skin that is the site of a lesion of granuloma fungoides is likely to be more "radiosensitive" than is the surrounding normal skin. Therefore, large doses are not indicated. When there are only a few scattered lesions, fractional, semi-intensive or subintensive treatments give excellent results. As a rule, three or four fractional or one or two semi-intensive or a single suberythema dose will suffice to make any one lesion disappear.

Fractional treatment is advised especially at the beginning of treatment, in order to avoid the possibility of toxemia. Later, if the eruption is stubborn, and localized, larger doses may be tried. As a rule, however, if small or moderate doses do not prove efficacious larger doses will be equally ineffectual. To insist on the continuation of *x*-ray treatment in cases that do not respond is poor policy.

Often it is necessary to irradiate all or a greater part of the body surface. For reasons given throughout this chapter it is advisable to begin with very small doses. It is customary to divide the body into from three to six areas, depending upon the distribution of the eruption, and expose each area once weekly. The dose at first is $H\frac{1}{8}$ S. D., unfiltered. After two or three weeks the dose may be increased, if necessary, to $H\frac{1}{4}$.

It is a good idea to make a differential white cell count about every two weeks. If there is a marked decrease of lymphocytes or if there are any signs of toxemia, irradiation should be discontinued temporarily.

If the eruption becomes recalcitrant, *x*-ray treatment should be stopped and other methods tried. After a few months' rest it is possible that irradiation will again prove efficacious.

Lesions situated in the eyebrows or on the scalp may be treated in the same way as lesions on the glabrous skin, the only exception being that the dose is limited to a total of $H\frac{3}{4}$ S. D., unfiltered, in one month. When necessary it is permissible to administer larger doses to hairy regions regardless of the effect on the growth of hair.

Filtration.—Filtered radiation is indicated when the lesions are more than 3 or 4 cm. in thickness. As a rule filtered radiation is not necessary, excepting in very large tumors, because the lesions of granuloma fungoides yield readily to *x*-rays of any quality. The author has never been able to cause the involution of lesions with filtered radiation that failed to yield to unfiltered *x*-rays—with the exception of very large tumors.

For further technical details the reader is referred to the following chapters: General Therapeutic Considerations, Filtered *X*-ray Technic, Practical *X*-ray Technic, Psoriasis.

Radium.—Radium may be used advantageously for the treatment of lesions that are more or less inaccessible to *x*-rays—mouth, external auditory canal, etc. Also, radium is suitable for circumscribed lesions on any part of the body. Obviously, *x*-rays are more suitable for extensive surfaces.

The usual controversy has arisen relative to the comparative efficacy of radium and *x*-rays in the treatment of this disease. Bayet, for instance, claims superiority for radium in the treatment of individual lesions. The author has found no difference in efficacy. He prefers *x*-ray treatment on account of the latitude and flexibility. Radium, in the author's experience, has not succeeded in causing the involution of a lesion that failed to disappear as a result of *x*-ray

treatment. In this connection, Ordway has succeeded in obtaining remissions with radium in cases of leukemia that were resistant to *x*-rays.

If a lesion is not more than 1 to 2 cm. thick penetrating beta rays may be used, the very "soft" beta rays being eliminated by a thin screen of aluminium. In the case of a tumor or a very thick patch, only the gamma rays should be employed. For further technical details the reader is referred to the chapter on radium technic.

LEUKEMIA CUTIS.

The author treated one case of generalized leukemia cutis with *x*-rays. There was some involution of lesions and some relief of the itching. Practically, the treatment was of very little value in this particular case. In several patients with circumscribed eruptions thought to be due to leukemia, the itching was arrested and the eruption disappeared.

The author has not found any literature dealing with this subject. However, the good temporary results obtained in splenic and splenomyelogenous leukemia, Hodgkin's disease and granuloma fungoides, warrants the belief that *x*-rays should be of value in the treatment of leukemia cutis.

LYMPHOGRANULOMATOSIS CUTIS.

Wise's well-known case of lymphogranulomatosis cutis (*Lymphadenosis cutis universalis*, associated with generalized erythrodermia and atrophy of the skin) was benefited by *x*-ray treatment, the *x*-rays having been administered by Remer in Dr. Fordyce's clinic. Itching was relieved and infiltrated plaques and boggy tumors disappeared.

HODGKIN'S DISEASE.

Hodgkin's disease is of interest to the dermatologist and he is often called in consultation to advise relative to diagnosis and treatment. Furthermore, in rare instances, there are skin manifestations in addition to the enlarged lymphatic glands. The literature dealing with *x*-ray and radium treatment of Hodgkin's disease is quite voluminous and all authors agree that in the majority of cases it is possible to effect a temporary clinical cure. Recurrence is the rule, but patients can be kept alive and in comfort for many years by the intelligent use of *x*-rays or radium combined with proper general medical treatment.

Alderson reports a case of Hodgkin's disease in which there were two large ulcers (Hodgkin's disease of the skin) which healed quickly when irradiated.

Irradiation of the lymphatic glands demands filtered *x*-rays or heavily screened radium. Technical details will be found in the following

chapters: Tuberculous Adenitis, General Therapeutic Considerations, Radium Technic, Filtered *X*-ray Technic, Practical *X*-ray Technic.

FIG. 153.—Hodgkin's disease, with very large glands of the axillæ and neck, before roentgenization.

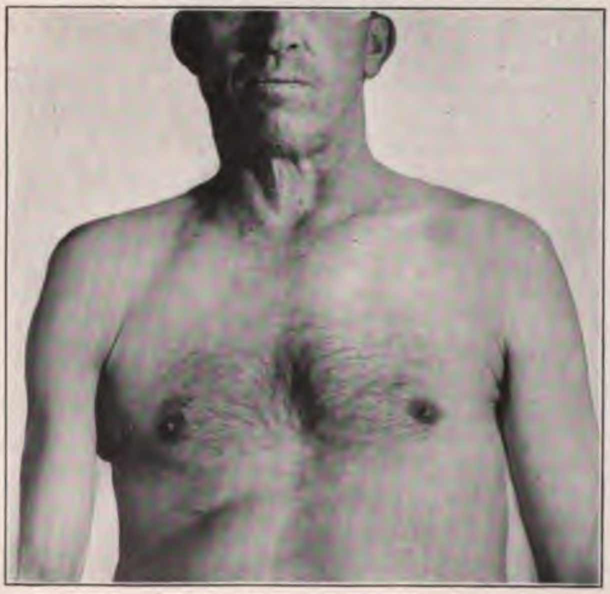

FIG. 154.—Same patient shown in Fig. 153, after fractional filtered treatment.

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CHAPTER XXIX.

DISEASES SUPPOSEDLY DUE DIRECTLY OR INDIRECTLY TO THE TUBERCLE BACILLUS.[1]

THE entities that will be discussed in this chapter are:

1. Lupus Vulgaris.
2. Lupus Erythematosus.
3. Tuberculosis Orificialis.
4. Tuberculosis Verrucosa Cutis.
5. Scrofuloderma.
6. Tuberculous Adenitis.
7. Erythema Induratum.
8. Sarcoid.
9. Tuberculides
    - Papulonecrotic Tuberculide.
    - Acnitis.
    - Folliclis.
    - Lichen Scrofulosorum.
    - Pernio.
10. Granuloma Annulare.

LUPUS VULGARIS.

With the exception of hypertrichosis and cancer, lupus vulgaris was the first cutaneous disease to be treated with *x*-rays. Schiff is reported to have cured a case of this affection as early as 1896. The first men to treat this disease were: In Germany and Austria, Schiff and Freund, Kümmel, Gocht, Gassmann and Schenkel, Hahn and Albers-Schönberg; in England, Scholefield, Holland, Hall-Edwards and Startin; in France, Belot, Gaston, Vieira and Nicolau, Béclère and Augé; in the United States, Jones, Knox, Greenleaf, Pusey, Allen and Pfahler.

Since these early reports the literature on the subject has become voluminous. At first it was thought that a specific had been found for the disease. A larger percentage of cases were cured then than now, because the early workers did not hesitate to effect a severe radiodermatitis in order to eradicate the disease. Later, when it was found that the sequelæ of radiodermatitis were so serious, *x*-ray treatment was administered in a more conservative manner and the effect on the disease was less spectacular.

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

Today there is a difference of opinion relative to the efficacy roentgen therapy in lupus vulgaris. This difference of opinion

FIG. 155.—Hypertrophic lupus vulgaris before x-ray treatment. The scar is the re of the excision of a former lesion.

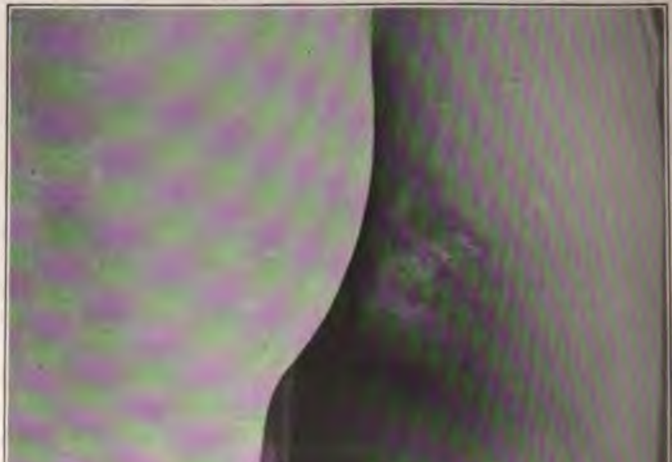

FIG. 156.—Same patient shown in Fig. 155, after one intensive, unfiltered x-ray treatment. No recurrence in twelve years.

occasioned partly by a lack of appreciation of the effect of x-rays different clinical types of the affection.

There are a great many adjectives used to describe the many var

tions in the clinical appearance of lupus vulgaris. For convenience we may combine these many clinical varieties into the following types:

1. Atrophic type.
2. Hypertrophic type.
3. Ulcerative type.
4. Multiple disseminated type.
5. Miscellaneous types.

Atrophic Lupus Vulgaris.—In this type the skin becomes atrophic and the affected area is studded with deep-seated, pinhead to lentil-sized nodules of a yellowish-brown color (apple-jelly nodules). The nodules may project above the niveau of the skin but, as a rule, the surface of the affected area is even although it may be scaly. The author has found the atrophic type of lupus vulgaris exceedingly recalcitrant to both *x*-rays and radium and, as a rule, it is necessary, in order to effect a cure, to support such treatment with tuberculin therapy or to remove the individual nodules by the method advocated by G. H. Fox. This consists of digging out the nodule with a dental burr and cauterizing the wound with carbolic acid or trichloracetic acid. The galvanocautery may also be used for this purpose.

In early cases, when the lesions are small, and before sclerosis and fibrosis have occurred, or in instances where the nodules are larger and nearer the surface, the results of roentgen therapy are better. The younger the lesion, the smaller the lesion, and the greater the rapidity of evolution, the greater will be the effect of the *x*-ray treatment. Such eruptions may disappear as a result of two or three intensive treatments. Older eruptions associated with atrophy and deep-seated nodules have resisted a year or two of intensive treatment. Recurrences are common after clinical cures.

Hypertrophic Lupus Vulgaris.—Here the nodules are larger (lentil to split pea), project above the surface of the skin and are coalesced. The coalesced nodules and hyperplastic skin together form elevated, firm but not hard, brownish-red plaques and tumors of various sizes. Small lesions of this type can be often permanently cured with one intensive treatment. Larger and older lesions are more stubborn, but, as a rule, this type of lupus vulgaris yields more readily than does the atrophic type of the disease, and recurrences are less common.

Ulcerative Lupus Vulgaris.—Ulceration may occur in either the atrophic or the hypertrophic type. Ulcers, under *x*-ray treatment, usually heal much more rapidly than the neighboring nodules involute. The results of roentgen therapy in ulcerative lupus vulgaris are often spectacular, especially when the disease involves the face and the nasal and buccal mucosæ. Unfortunately recurrences are common. During treatment the ulcers should be kept clean and free from crusts, and individual nodules destroyed by other methods of treatment.

Multiple Disseminated Lupus Vulgaris.—The individual scattered nodules of this type have undergone rapid involution in the few cases treated in the author's laboratories.

Miscellaneous Types.—The serpiginous type of lupus v
very rebellious if the nodules are small and deeply embe

Fig. 157.—Lupus vulgaris of the hypertrophic type with involvement of t
(Courtesy of Dr. J. F. Schamberg.)

Fig. 158. Same patient shown in Fig. 157. after fractional x-ray tre
(Courtesy of Dr. J. F. Schamberg.)

the nodules are larger and more superficial the affection is less stubborn. If ulcerated, the ulcers will usually heal under the influence of the *x*-rays.

159.—Lupus vulgaris of hypertrophic or verrucous type before treatment. Patient referred by Dr. F. Steinke.

G. 160.—Same patient shown in Fig. 159, after two subintensive *x*-ray treatments. erous nodules still remain. The case is now one of the atrophic type and for a result other methods usually must be combined with *x*-ray treatment.

he early literature contains reports of good results obtained in us tumidus. The author has treated only one example of this type. er several months of intensive filtered treatment there was a very rked improvement but the patient was not cured.

omparative Value of Roentgen Treatment.—Roentgen therapy has replaced phototherapy in point of efficacy. The Finsen treatment

has given better results than have thus far been obtained with either x-rays or radium. Forchhammer, in a statistical report based on 1200 unselected cases of lupus vulgaris treated at the Finsen Light Institute between 1896 and 1906, gives the following results of the treatment: Cures, 60 per cent.; under treatment, 18 per cent.; treatment

FIG. 161.—Lupus vulgaris involving the nasal mucosa, before treatment. It was necessary for the patient to breathe through the mouth.

FIG. 162.—Same patient shown in Fig. 161 after several subintensive treatments. The pinched condition of the nose is the typical result of lupus.

discontinued, 11 per cent.; dead, 11 per cent. Of the total cured (721) 33 had been free from recurrence for ten years or more; 289 for

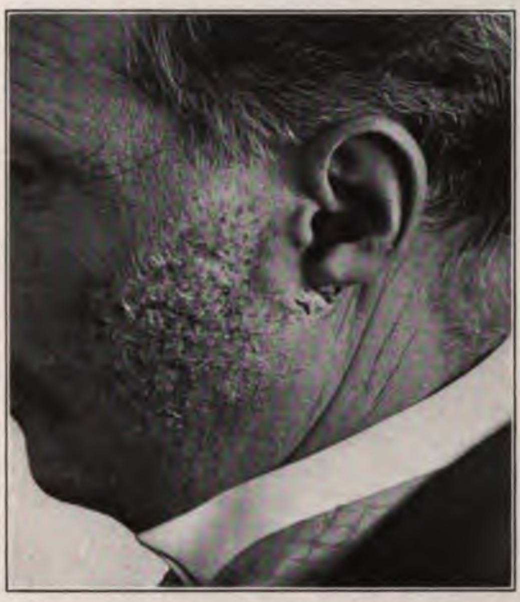

FIG. 163.—Lupus vulgaris clinically resembling lupus erythematosus, before treatment.

FIG. 164.—Same patient shown in Fig. 163. Depigmentation is due partly to the disease and partly to x-ray treatment. This white area can be successfully hidden with the stain given in Chapter XV.

from five to ten years; 306 for from two to five years; and 93 for less than two years. In a further study, the subjects are divided into initial cases and inveterate cases. In the initial cases 76 per cent. were cured, while in the inveterate cases 51 per cent. were cured (Ormsby). The author has not been able to obtain as good results with roentgen therapy nor has he encountered roentgen or radium statistics that show results in unselected cases of lupus vulgaris that are the equal of those quoted supra. For various reasons the Finsen treatment has been found impracticable in this country and substitute methods such as the Kromayer and Alpine lamp treatment have, in most hands, proved disappointing. The Finsen treatment not only cures a high percentage of cases but it does so without producing injury or sequelæ.

Small lesions, suitably situated, can be ablated or curetted and cauterized. Surgical methods, however, are necessarily limited to selected cases. The same is true of tuberculin therapy, refrigeration, fulguration and other methods of treatment.

It is probable that irradiation may in point of efficacy be placed second to phototherapy. It will certainly cure a larger proportion of unselected cases than will any method other than the Finsen treatment.

Combined Treatment.— Irradiation may be combined with phototherapy, but it is not wise to apply ultraviolet rays and x-rays or radium at the same time. The two methods may alternate or one method may follow the other. The author has tried this scheme in obstinate cases but the results have not been encouraging. The use of tuberculin and Fox's method (see supra) has proved of distinct value when combined with irradiation, especially in the atrophic type. It is of the utmost importance, in the ulcerative type, to provide drainage and to keep the ulcers clean and free from crusts. A very small amount of ultraviolet rays may be advantageously combined with irradiation in the treatment of open ulcers. Refrigeration and caustic and irritating ointments are contra-indicated during irradiation.

Lupus Vulgaris, X-rays and Cancer.—Stümpke encountered two cases of lupus vulgaris that had received fractional x-ray treatment for many months. Epithelioma developed in the scar tissue in both patients. Stümpke calls attention to the fact that he has seen 150 cases of lupus vulgaris and he never noted epithelioma in any case that had not received x-ray treatment. The two patients with epithelioma also showed x-ray sequelæ.

MacLeod reports a patient with lupus vulgaris who presented both x-ray sequelæ and epithelioma. Gaucher and others have seen similar cases. The author has seen 3 cases where epithelioma developed in a scar that was caused partly by the disease and partly by a severe radiodermatitis.

It is a well-known fact that epithelioma occurs as a sequel in lupus

vulgaris that has not received *x*-ray treatment. The epithelioma is always of the malignant, metastatic, prickle-cell type. Ormsby states that this sequel occurs in from 2 to 4 per cent. of the cases. Lieberthal, Zeisler, Pusey, Anthony, Hyde and others have seen epithelioma develop as a sequel to lupus vulgaris in patients who had not received *x*-ray treatment.

There is absolutely no proof that irradiation increases the natural tendency of epithelioma to develop as a sequel to lupus vulgaris unless irradiation has been pushed to the point of producing the so-called *x*-ray skin. *X*-ray sequelæ are likely to be the forerunners of cancer, whether such sequelæ are or are not associated with lupus vulgaris. Disregarding the cases of lupus vulgaris in which epithelioma develops in an *x*-ray sequela, there is no evidence in the literature to show that epithelioma as a sequel to lupus vulgaris is more common today than before the advent of roentgen therapy.

FIG. 165.—Lupus cured with *x*-rays several years ago. Patient now shows epithelioma developing in the lupus scar.

Lupus vulgaris may cause considerable disfigurement. The usual sequelæ are scars and atrophy. It not infrequently happens that irradiation is blamed for these sequelæ.

Technic.—It is the author's experience that intensive or subintensive irradiation is more efficacious in lupus vulgaris than is fractional treatment. The routine is to administer about H¾ S. D. unfiltered, every four weeks. The dose will vary with the location of the affected area and the age of the patient. The dose will range from H½ S. D., in children to H1 S. D. to H1½ S. D. in adults and aged individuals.

While the disease will recover more quickly if the dose is sufficient to effect a sharp reaction it is preferable to avoid even slight reactions. In many cases of lupus vulgaris it is necessary to continue the treatment over several months and if each treatment, or if several of the treatments result in even a first-degree reaction, the ultimate outcome may be serious *x*-ray sequelæ. The aim should be, therefore, to administer each month as much as the skin will tolerate without visibly reacting. It is difficult to determine just how long such treatment may be continued without serious injury. In obstinate cases it seems advisable to limit the number of monthly treatments to from eight to twelve. This amount of irradiation is likely to produce visible atrophy but no sequelæ of a severe nature. The skin should be carefully inspected at each treatment for evidence of injury. If an eruption has not disappeared after this amount of treatment it is advisable to discontinue irradiation and depend upon other methods of treatment. Not infrequently, after several treatments the eruption, with the exception of a few nodules, will disappear. It is unwise to depend upon irradiation to cause the involution of these remaining nodules. They can be quickly destroyed by other methods of treatment.

While the principal reason for avoiding severe *x*-ray reactions is to lessen the danger of serious sequelæ there is also another reason, namely, severe toxic symptoms. Pusey (quoted by White and Burns) tells of a patient afflicted with widespread lupus vulgaris. The affected areas were irradiated until a reaction developed. The reaction was associated with alarming systemic symptoms, simulating a tuberculin reaction. This occurred on three occasions. The third reaction proved fatal. The moral is to use suberythema doses and not to treat too large an area at one time.

Filtration is often indicated in this affection. Especially is this true when the disease involves the mucosa of the nose, mouth and throat. In such instances, with filtered radiation, the lesions of the mucous membranes will usually disappear under the influence of radiation applied to the cutaneous eruption on the face. Pfahler and the author have reported clinical cures accomplished in this manner. Whether or not filtration is advisable in all cases of lupus vulgaris is an open question—it cannot be answered at the present writing.

Lesions of lupus vulgaris are of various sizes and occur in many parts of the body. The method of handling lesions of different size, shape and position will be found in the chapter on General Therapeutic Considerations. It is advisable not to shield too close to the lesion as the disease is likely to extend beyond the visible margin.

Radium.—A review of the work done by Wickham and Degrais, Simpson, Newcomet, Finzi and others, together with personal experience, shows that the results obtained with radium, in the treatment of lupus vulgaris, are about the same as those associated with the use

of the x-rays. The best results have followed irradiation of a strength that caused destruction of the nodules by necrosis; also more conservative irradiation combined with other methods of treatment.

In some small, superficial lesions of lupus vulgaris the beta rays have seemed more efficacious than have either x-rays or gamma rays. The "soft" beta rays should be eliminated by a screen of from $\frac{1}{10}$ to $\frac{1}{2}$ or 1 mm. of aluminium or its filtration equivalent in glass or other substance.

Radium is especially indicated when the lesions are situated in inaccessible locations—nasal and buccal cavities, throat and conjunctivæ.

LUPUS ERYTHEMATOSUS.

Schiff and Freund were probably the first to treat lupus erythematosus with the x-rays (1898). Their report was soon followed by those of many roentgenologists and dermatologists—Sjogren and Sederholm, Startin, Jutassy, Lee, Török and Schein, Béclère, Belot, Hall-Edwards, Pusey and others.

At first the results were very promising and were superior to those obtained today, that is, the immediate results. The early workers did not hesitate to produce severe reactions and the immediate therapeutic effect on the disease was often very strking. Later, when it was ascertained that the brilliant result was but temporary and that very undesirable sequelæ often followed radiodermatitis, the treatment was applied more cautiously and the effect on the disease was less spectacular.

A review of the literature for the last fourteen years shows that the x-rays have been used less and less in the treatment of the disease. Zeisler, Clark, Schmidt, Hartzell, Montgomery, Winfield and many others record good temporary results without the production of radiodermatitis. Fordyce, Robinson, Bronson and others reported cases that were made worse, or failed to improve, or improved but little, as a result of the treatment.

Value of Roentgen Therapy.—The consensus of opinion today among dermatologists is that roentgen therapy is of little real value in the treatment of lupus erythematosus. Its value is certainly less than that of ultraviolet-ray therapy, refrigeration and other methods. Nevertheless, the x-rays, if properly used in well-selected cases, will occasionally cause involution of lesions that have resisted other methods of treatment.

Types of Lupus Erythematosus.—It is important for the roentgenologist to know that lupus erythematosus occurs in two general types—discoid or chronic, and disseminated or acute. It is well to remember, also, that the course of the affection is very uncertain. Discoid lesions are likely to persist for many years or they may undergo spontaneous involution only to recur subsequently. The disseminate type often disappears spontaneously or as a result of local

applications in a few weeks or months. Rarely it persists and spreads and the patient dies of tuberculosis; more often of nephritis and asthenia (Jadassohn).

Technic.—For the disseminate type, especially when associated with acute inflammatory symptoms, the treatment should be fractional or subfractional. The discoid lesions may be given subintensive treatment. It is advisable to avoid even a first degree reaction

Fig. 166.—Lupus erythematosus.

Fig. 167.—Same patient shown in Fig. 166, after radium treatment.

if possible. A mild x-ray reaction is likely to cause the disease to spread and may add to the atrophy and telangiectasis occasioned by the affection. It is well to remember that while the x-rays may cause involution of a lesion of lupus erythematosus they exert little if any effect on the future course of the disease. For this reason it is not justifiable to push the treatment to the point of visible cutaneous injury. Furthermore, it is not advisable to persist in the roentgen

treatment of a stubborn lesion. If the lesion does not disappear as a result of three or four months of fractional or subintensive treatment, experience has shown that it will not be favorably influenced by a continuation of such treatment.

The nose is a favorite site for lesions of this disease. Details relative to the method of applying x-rays to the nose and to convex and concave surfaces, to lesions of various sizes and shapes, to lesions on the eyelids and other locations, etc., will be found in the chapter on General Therapeutic Considerations.

There is a difference of opinion relative to the advisability of confining the radiation strictly to the lesion or to include a small area of normal skin around the lesion in the field of radiation. With doses sufficient to effect a first-degree reaction the author has seen peripheral spreading of the lesion when the radiation has been confined to the lesion and, also, when the normal skin adjacent to the lesion has been irradiated. While a first-degree reaction will often have a beneficial effect on discoid lesions the converse is also true. Quantities that do not effect a reaction rarely if ever make the lesion worse, although such treatment may accomplish little if any good. Scalp lesions may be treated with a full epilating dose (H1 or H1¼ S. D.). For details relative to the treatment of scalp lesions see chapter on Psoriasis and chapter on Tinea Tonsurans.

Comparative experiments with filtered and unfiltered radiation have yielded similar results. Apparently there is nothing to be gained by filtration in the roentgen treatment of this disease.

Sequelæ.—Lupus erythematosus causes atrophy, wrinkling, telangiectasia and permanent alopecia. The picture at times is suggestive of x-ray sequelæ. In cases that have received roentgen-ray treatment it is often impossible to decide how much of the disfigurement is due to the disease and how much is due to the treatment. Epithelioma occurring in patches of lupus erythematosus or in the atrophic skin following involution of lesions, in cases that have not been irradiated, have been reported by Pringle, Dyer, the author and others.

Combined Treatment.—When applying radiation to acute lupus erythematosus it is advantageous to also apply such soothing remedies as zinc oxide ointment and calamine lotion. In the chronic type, when stimulating and caustic remedies (resorcin, lotio alba, liquor potassæ, etc.) are indicated, it is advisable not to combine the use of such remedies with irradiation unless the x-ray dose is very small. Ultraviolet rays and especially refrigeration should not be used during x-ray treatment.

Radium.—The results obtained with the beta rays of radium are better than those obtained with either x-rays or gamma rays. Unfortunately, however, the difference is not great.

Wickham and Degrais, with unfiltered beta radiation sufficient in

amount to provoke a sharp reaction, have obtained good temporary results in the discoid type. They advise sharp but not severe reactions and also that the skin in the immediate neighborhood of the lesion be included in the treatment. Simpson, Knox, Newcomet and others have testified to the favorable results sometimes obtained with radium in lupus erythematosus.

As a result of comparative clinical experimentation with *x*-rays and radium in this disease, the author feels safe in saying that radium is the better agent. There is no apparent difference in the effect on the disease of *x*-rays and gamma rays, but there is a difference with beta rays, especially those of "soft" and "medium" quality. The best results have been obtained with an unfiltered applicator or with very slight filtration (equivalent of $\frac{1}{10}$ mm. Al.), depending upon the thickness of the epidermis. If the horny layer is very thick it is advisable to remove it by means of a soap poultice (maceration) before applying the rays.

The effect on the disease is greatest when the dose is sufficient to produce a sharp reaction. A reaction resulting from "soft" beta rays, even when severe, heals quickly and is far less likely to be followed by telangiectasia, atrophy and keratoses than are reactions subsequent to applications of *x*-rays or gamma rays. But regardless of technic many cases of lupus erythematosus fail to improve under radium treatment. It is advisable to attempt the desired result with doses that are within the amount required for a reaction, leaving the stronger doses for chronic lesions that resist all forms of treatment.

TUBERCULOSIS ORIFICIALIS.

[illegible] may be secondary [illegible] etc. Both [illegible] treatment of [illegible] mucous mem- [illegible] vulgaris of [illegible] tuberculous [illegible] may [illegible] penetrating [illegible] throat [illegible] are more [illegible] although [illegible]

[illegible]

inaccessible lesions are considerable. This question is discussed in the chapter on Radium Technic.

FIG. 168.—Tuberculosis orificialis before treatment.

FIG. 169.—Same patient shown in Fig. 168, after one intensive treatment and one subintensive treatment.

TUBERCULOSIS VERRUCOSA CUTIS.

True examples of tuberculosis verrucosa cutis are likely to be found recalcitrant to both *x*-rays and radium. The author has cured a number of cases of verruca necrogenica with one intensive *x*-ray treatment. Such favorable results are not often obtained, however, in well-developed verrucous tuberculosis. The result will depend largely upon the extent of the involved surface and the thickness of the epidermis, especially the horny layer. All cases so far treated by the author have been cured in from three to eight intensive treatments. If the hyperkeratosis is considerable the lesion is closely shielded and a dose of filtered *x*-rays (H1¼ S. D.) is administered. The hole in the lead shield is then enlarged so that a half inch of normal skin around the lesion is included in the field of radiation. Another dose of similar amount is applied. The lesion will have received a dose of H2½ while the apparently normal skin will have received half the amount, thus the normal skin will not be injured. In some instances it is permissible to administer as much as H3 S. D. or even H4 S. D. filtered through 3 mm. of aluminium to the lesion itself. The dose will depend upon the thickness of the horny layer. In any event it is advisable not to give more than H2½ at the first sitting. The treatments are given as a routine at intervals of one month.

FIG. 170.—A small lesion of tuberculosis verrucosus cutis before treatment.

FIG. 171.—Same patient shown in Fig. 170, after one intensive *x*-ray treatment.

A quick method of curing this affection is to remove the bulk of the diseased tissue by means of the curette and then apply an intensive dose of unfiltered *x*-rays. The objection to such procedure is that the tubercle bacilli may find entrance into the general circulation at the time of the curettage.

There are few references in the literature dealing with the use of radium in this affection, and there has been no personal experience. Simpson, Wickham and Degrais and a few others have obtained good results. There is no reason why radium should not have exactly the same effect as the *x*-rays. In using radium the beta rays should be eliminated by suitable filtration.

SCROFULODERMA.

The term scrofuloderma implies ulceration of the skin and subcutaneous tissues associated with underlying, suppurating tuberculous glands, tuberculous osteomyelitis, or other deep-seated tuberculous foci. For convenience we can also include superficial tuberculous ulcers that do not fit into any clinical entity and which are often spoken of as ulcerative tuberculosis cutis. As a rule, these superficial ulcers heal rather promptly when irradiated; occasionally they are recalcitrant.

Ulcers and sinuses associated with underlying tuberculous foci often respond wonderfully well to irradiation, especially if the treatment is directed at the deep foci (filtered radiation) and good drainage is established. The results in such cases have been among the most noteworthy achievements of roentgen therapy. The author has seen remarkable clinical cures in cases of suppurating tuberculous adenitis and tuberculous osteomyelitis with involvement of the underlying tissues and in the so-called scrofulous gumma after the contents of the abscess have been evacuated. Furthermore the percentage of recurrences has been small. In such affections it is advisable to prescribe internal medication, diet, hygiene and in many instances surgical aid may be required.

The principal technical requirement is to apply lethal doses to the deep foci without injury to the overlying tissue. This is done by distance, filtration and cross-fire, technical questions that are discussed in detail in the chapters on Radium Technic, Filtered Roentgen-ray Technic and General Therapeutic Considerations. Useful and practical points will also be found in this chapter under the heading of Tuberculous Adenitis.

Intensive irradiation at monthly intervals is indicated; cross-fire treatment should be given whenever possible; radium and *x*-rays appear to give the same results.

Bowen, Ratera, Nadler, Denks and others report very interesting examples of scrofuloderma associated with tuberculous adenitis, that were cured with *x*-rays. Denks's report includes scrofuloderma associated with various types of surgical tuberculosis. Of 323 cases there were 43 fungoid lesions connected with the large articulations. Of these, 35 per cent. were clinically cured, 25 per cent. improved, 15 per cent. did not improve and 25 per cent. failed to continue the treatment. There were 101 cases associated with tuberculous adeni-

tis of which 82 were cured. Lesions connected with small articulations showed a percentage of cures of 84. There were 67 cases of large fistulæ, half of which were cured and 54 small fistulæ, 60 per cent. of which were cured. Williams was one of the first to recognize the value of roentgen therapy in scrofuloderma and tuberculous adenitis.

TUBERCULOUS ADENITIS.

Tuberculous adenitis is not a dermatosis. The affection is of interest to the dermatologist because it is associated with the various tuberculous affections of the skin. Also because of the disfiguring scars often caused by the disease and by the treatment, especially in tuberculous adenitis of the cervical region.

Roentgen therapy has given excellent results in this affection. The author's experience is limited to the treatment of thirty cases of cervical tuberculous adenitis. Twelve cases were clinically cured. In three patients the glands remained the same size but a roentgenogram showed them to be calcified. In ten cases the glands were reduced in size but they could be palpated and were not calcified. Five patients failed to remain under treatment. The cured cases were children or adolescents.

Tuberculous adenitis together with scrofuloderma was one of the first affections to be treated successfully with the *x*-rays, the earliest reports having been made in this country (Williams, Childs, Rodman and Pfahler, Varney and Pusey). In recent years the literature on this subject has become voluminous. Good articles, many of which contain excellent illustrations and careful technical descriptions, have been published by Boggs, Weil, Feldstein, Leonard, Knox, Strunsky, Fritsch, Mowat and many others.

Tuberculous adenitis is a surgical affection and, also, it is one that requires general medical supervision. Therefore it is advisable that the roentgenologist work in collaboration with surgeons, internists, pediatricians, laryngologists, etc., when attempting to select cases for roentgenization. The results of roentgen therapy have been so good that, if there is no contra-indication to such treatment in the minds of internists or surgeons, the *x*-rays or gamma rays, along with general medical measures, should be given a trial in order to avoid the scarring and shock associated with surgical intervention.

Roentgen therapy is not an unmixed blessing, however. Surgeons aver that, in cases that come to operation after considerable irradiation, they find it difficult to perform a satisfactory operation on account of the sclerotic tissue. If this is true it is fortunate that very few such patients find it necessary to submit to the knife. Furthermore, it is not necessary to push the treatment to the point of sclerosis of normal tissue. A more important point is the possibility of undesirable *x*-ray or radium sequelæ, a question that will be considered later.

While there are no available comparative statistics it seems to be the prevailing opinion among internists and roentgenologists that irradiation together with general medical treatment is more successful in a majority of cases than is surgery, in point of clinical cure, permanent cure, discomfort and disfigurement. Men who hold this

172.—Tuberculous adenitis before treatment. (Weil.)

Fig. 173.—Same patient shown in Fig. 172, after treatment. (Weil.)

pinion consider that surgery should be limited to complicating factors ch as tuberculous tonsils and necrotic glands. The author is of e opinion that the selection of the case should be left to the surgeon

174.—Tuberculous adenitis before treatment. (Weil.)

Fig. 175.—Same patient shown in Fig. 174, after treatment. (Weil.)

and internist after consultation with a roentgenologist and, perhaps, other specialists. Certainly there are instances where surgery is indicated, cases where surgical intervention is imperative and cases where surgery will give better results than will irradiation. It is questionable if the roentgenologist should be the judge.

of this uncommon affection. Darier reports good results with x-rays, his first report having been made in 1904. H. Fox failed to cure an extensive case of sarcoid with x-rays in which there were numerous large and rather deep-seated nodules. There was some improvement but it was necessary to resort to other methods of treatment in order to effect a cure. The failure may have been due to the fact that the individual doses were too small and also because unfiltered radiation was employed. Zeisler treated a generalized eruption of Boeck's sarcoid with both x-rays and radium. The result was slight involution of the lesions.

FIG. 176.—Sarcoid of Boeck before treatment. One lesion on the temporal region has already been treated. Atrophic remains of this lesion can be seen.

FIG. 177.—Same patient shown in Fig. 176. The lesions on the forehead and those on the cheek were treated with x-rays. The lesions on the eyelids and nose and in the eyebrow were treated with radium. There is permanent loss of hair in some parts of the eybrow.

Boeck's sarcoid occurs in two general clinical types. In one type the lesions consist of rather superficial plaques. In the other type the lesions consist of various-sized nodules situated deep in the true skin. Good results may be obtained in the superficial cases with unfiltered x-rays or with penetrating beta rays. The deeper and larger lesions should be treated with filtered x-rays or gamma rays. The same is true of the subcutaneous sarcoid of Darier-Roussy and allied conditions such as tuberculosis of the hypoderm described by Wende.

FIG. 178.—Sarcoid of Darier-Roussy type, before roentgenization.

FIG. 179.—Same patient shown in Fig. 178, after *x*-ray treatment.

The dose is intensive or subintensive, administered about once a month.

Sarcoid, especially Boeck's type, shows a predilection for the face. In this location, especially, it is advisable not to effect an erythema. The disease itself is likely to be followed by atrophy and the disfigurement will be worse if telangiectasia and additional atrophy is occasioned by the treatment. It is preferable, therefore, to administer several suberythema doses rather than to attempt a cure in one treatment.

THE TUBERCULIDES.

Ormsby has found *x*-rays of service in papulo-necrotic tuberculide. Knowles and Ketron treated cases of acnitis with *x*-rays and noted involution of the eruption. Bronson obtained a similar result in a case of folliclis.

The tuberculides are widespread, evanescent, recurring eruptions. Recurrences cannot or at least have not been prevented by roentgen therapy. The natural course of the eruption apparently can be shortened by the administration of fractional, unfiltered treatment.

FIG. 180.—Granuloma annulare before treatment.

FIG. 181.—Same as Fig. 180, after one intensive *x*-ray treatment.

Lichen Scrofulosorum.—In recent years this affection has been removed from the tuberculides and placed among the cutaneous tuberculoses. The author has treated two cases of this affection with fractional, unfiltered radiation. In both instances the eruption disappeared after irradiation had been continued for four months. The involution of the eruption may have been spontaneous or it may have been due to improved general hygiene. The disease in both patients had been present for several months before *x*-ray treatment was instituted. No topical applications were made.

Pernio.—The pernio of supposed tuberculous origin may at times be benefited by fractional treatment, especially when there is ulceration. Fujinami has found such treatment useful in frost-bite pernio.

GRANULOMA ANNULARE.

There is no precedent for placing granuloma annulare in the tuberculosis group. It is discussed in this group partly for convenience

and partly because many dermatologists consider the disease to be more or less intimately connected with tuberculosis.

The author has found the *x*-rays to be particularly efficacious in the treatment of granuloma annulare. Four cases of this rare disease were treated. In no instance was it necessary to give more than two intensive treatments and usually the lesions involuted subsequent to a single application of the radiation. The lesions are shielded closely, and each lesion is given an intensive dose. If involution is not complete in a month a second application is made. Papules and small nodules are treated with unfiltered radiation; large nodules are treated with filtered radiation. The lesions do not recur but new ones develop.

Hartzell, White, Ormsby, Goldenberg and Chargin and others have reported good results with *x*-rays. Apparently no cases have been treated with radium but it can be taken for granted that both agents will have the same effect.

It will be interesting to observe the effect of irradiation on erythema elevatum diutinum, a disease that Hartzell and others believe is but a clinical variety of granuloma annulare.

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CHAPTER XXX.

VERRUCOUS LESIONS AND ERUPTIONS.[1]

The following entities will be discussed in this chapter:

1. Verruca Vulgaris.
2. Miscellaneous Types of Verruca and Papilloma.
3. Cornu.
4. Callositas (Verruca Plantaris).
5. Keratosis.
6. Leukoplakia.
7. Kraurosis Vulvæ.
8. KeratosisFollicularis (Darier's Disease).
9. Xeroderma Pigmentosum.
10. Acanthosis Nigricans.

VERRUCA VULGARIS.

The author has had such splendid success with the roentgen-ray treatment of common warts that there is no hesitancy in advising such treatment as the method of election. A total of 128 cases was treated, most of which had multiple lesions. Of this number the result in 40 is unknown. Of the remaining 88 cases, 74 were cured, mostly as the result of one or two treatments. There was improvement in 6 cases and no improvement in 8 cases. Twenty-six were cured in one treatment. There were no recurrences. It is difficult to understand the 8 failures. In running over the history cards it was found that location did not seem to make any difference. The lesions varied in size, but at times large lesions involuted promptly while small ones failed to be benefited. The fact is that there are some common warts that will not undergo involution under the influence of the *x*-rays. If a lesion has not disappeared after three or four intensive or hyperintensive doses at monthly intervals, it is unwise to persist in the treatment. If the treatment is continued beyond this point, a third-degree radiodermatitis may develop insidiously under the wart. This is an important fact and should be borne in mind.

The advantages of irradiation are: no danger of infection; promptness and permanence of cure; absence of pain and scarring; rapidity and facility of the treatment.

The lesion usually disappears in about three weeks subsequent to the first treatment. It may improve considerably in the second and third weeks and regain its original size in the fourth week. If so, it usually disappears three weeks subsequent to the second treat-

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

ment. Rarely, irradiation of one wart in a case where there multiple lesions scattered over both hands, may be followed by disappearance of all warts on one or even on both hands. Phenom

Fig. 182.—Verruca vulgaris before treatment. Note that the lesion extends under the side of the finger-nail.

Fig. 183.—Same as Fig. 182, after intensive x-ray treatments. There no recurrence. Two months after last treatment it was impossible to de mine the position of the former lesi

Fig. 184.—Verruca vulgaris with multiple lesions, before treatment.

Fig. 185.—Same as Fig. 184, after one subintensive x-ray treatment.

of this kind have been noted by Delbanco, Halberstaedter, the author and others.

Perthes (1901) and Sjogren and Sederholm (1903) were the first to call attention to the value of roentgenization as a treatment for the common wart. Since then most roentgenologists have obtained satisfactory results. A few (H. Fox and others) have not found irradiation effective and prefer other methods.

Technic.—The common wart is composed of a very thick rete (acanthosis) and, as a rule, there is considerable thickening of the horny layer (hyperkeratosis). For these reasons it is permissible to apply a larger dose than would be tolerated by the normal skin without a sharp reaction. It is essential that the normal skin around the wart be protected with lead foil to the very edge of the lesion. The first dose should be H1 S. D. unfiltered. In many instances this amount will suffice to effect a permanent cure, the wart disappearing in three or four weeks. If the lesion, instead of disappearing, is considerably reduced in size as a result of the first treatment, another dose of the same size is administered four weeks subsequent to the first application. If the lesion, as a result of the first treatment, has not become smaller, and there has been no reaction, the second dose may be increased to H1¼ or H1½ S. D. In large warts it is possible to give as much as H2 S. D., unfiltered, without effecting a reaction.

It is advisable here to interject an important warning. If the dose is sufficiently large there will, of course, be a reaction. But this reaction is not noticed as an erythema. The wart becomes sensitive to the touch and perhaps a little larger, the increase in size being due largely to the inflammation of the true skin. At times evidence of inflammation may be noted in the skin around the lesion, skin that was not in the field of radiation. It is important to bear these facts in mind, otherwise a reaction might be overlooked, a second application might then be made before the reaction had disappeared, with the possibility of a third-degree radiodermatitis. If the evidences of reaction as above outlined are manifest, the next treatment should not be given for at least two weeks subsequent to subsidence of the reaction. Some warts are very vascular and react to comparatively mild doses. This fact, together with the fact that the thickness of the horny layer and epidermis varies in different warts, constitutes the basis for the conservative first dose, namely, H1 S. D.

In cases of multiple verrucæ, with numerous lesions scattered over the hands or other parts, it is too much of an undertaking to treat each lesion separately. If there are only a few warts on a fairly level surface it requires only a few minutes to cut a hole for each wart in a piece of lead. The whole affected area may then be exposed to the routine dose. Lesions that are not on a level surface must, of course, be separately exposed. If the lesions are too numer-

ous for the method just outlined, the entire surface, lesions and normal skin may be given a suberythema dose (H¾ S. D.) and this may be repeated each month for three or four treatments if necessary. In cases of this kind it is a good plan to apply a thick zinc or bismuth paste to the normal skin between the lesions.

A rather favorite location for the common wart is at the edge of a finger-nail. It often extends under the nail. In such instances it is advisable to cut the nail until the verrucous surface is fully exposed before applying the rays. Not infrequently a wart will extend entirely around a nail and involve the lateral surfaces of the finger. Here we are dealing with a convex surface and it is often necessary to make two exposures, one exposure to each side, care being taken to protect first one side and then the other and, also, to prevent overlapping (see chapter on General Therapeutic Considerations).

The common wart may involve the mucous membranes of the lip, nose and eyelid. In such locations it is often more convenient to use radium.

Filtration.—There are theoretical grounds for an argument in favor of filtered radiation in the treatment of verruca vulgaris. Naturally the author has tried both filtered and unfiltered radiation and in the majority of instances no difference was noted in the matter of efficacy. In no instance, excepting in unusually large warts, has it been possible to cause the disappearance of a lesion with filtered radiation that failed to involute under the influence of unfiltered radiation. Very large warts, however, should be treated with filtered rays. The first dose should be about the same as for unfiltered radiation, namely H1¼ S. D., and this can be increased if necessary. Greater care is required in the case of filtered radiation, to avoid a reaction, than in the case with unfiltered radiation. The explanation is that with filtered radiation there is less absorption by the horny layer and rete. Therefore it is not advisable to administer full erythema doses of filtered radiation without first determining the toleration. The reasons for favoring unfiltered radiation are that considerably less time is required to administer the dose, there is no greater safety with filtered radiation and with the exception noted supra, efficacy appears to be the same with both filtered and unfiltered radiation. The reader is here referred to the paragraph on filtration under the heading of "Plantar Warts" in this chapter.

Radium.—The author's experience with radium in the treatment of verruca vulgaris is limited to a comparatively few cases. In most of these cases the lesion has been in the nostril, at the vermilion border of the lip or at the mucocutaneous junction of the eyelid. The results have been splendid with both penetrating beta rays and gamma rays, depending on the size and thickness of the lesion.

Lesions situated in the nostril can be irradiated by means of a radium tubular applicator. Lead foil is wrapped around the tube; a small window or diaphragm is cut in the lead close to one end of

the tube; with adhesive plaster the tube is fastened to one end of a wooden tongue depressor; the wood acts as a handle by means of which the exposed part of the tube can be held against the lesion for the desired length of time; the glass wall of the tube provides sufficient filtration for most cases. The same scheme is useful for lesions situated at the inner canthus or at the border of an eyelid. It is often possible to cross-fire large lesions with beta rays from a tubular applicator. In general the statements made in discussing the roentgen-ray treatment of warts will apply to the use of radium for the same purpose. For further details relative to technic the reader is referred to the chapter on Radium Technic.

Abbe, Finzi, Knox, Wickham and Degrais and in fact, most radium therapeutists testify to the efficacy of radium in the treatment of verruca vulgaris.

MISCELLANEOUS WARTS.

Papillomata of the skin and mucous membranes will often disappear subsequent to irradiation. Recurrences are uncommon. Abbe and others have obtained good results with radium in the treatment of papillomata of the tongue. The author has encountered lesions that disappeared promptly and lesions that failed to improve at all when irradiated. More experience is required in order to classify the various types of warts and papillomata and to permit a proper selection of cases. The technic of application does not differ from that given for the treatment of verruca vulgaris.

The author has found the flat juvenile wart very recalcitrant to both radium and *x*-rays. At times the result is good, but on the whole treatment has been disappointing. Allen reports a patient with flat warts scattered over the trunk. The eruption disappeared, apparently as a result of roentgenization. The histology, however, was that of porokeratosis. Lustgarten made a clinical diagnosis of multiple senile or seborrheic warts. The lesions of both verruca planum juveniles and the flat warts of adults have not yielded well to irradiation excepting in a few instances. It is possible that better results will be obtained after a longer experience.

Pfahler noted the disappearance of multiple verruca of the bearded region as a result of roentgenization. The treatment did not prevent the formation of new lesions. Personal experience with this type of wart has not been satisfactory.

Wickham and Degrais, Newcomet and others report good results with radium in the treatment of warts or papillomata of the scalp. Also vegetations of the vulva and glans penis associated with gonorrhea. The author treated one case of condyloma acuminatum with *x*-rays without benefit. Schultz found that it required dangerous doses to cause involution in this type of wart.

CALLOSITAS (VERRUCA PLANTARIS).

The first recorded instance of the successful treatment of a plantar wart so far located is in a footnote on page 276 of Wickham and Degrais' book published in 1912. The lesion was treated with radium. The possibilities of roentgen therapy and radium therapy in this affection seem to have been overlooked, for there are very few references in the literature bearing on the subject.

Hazen and Eichenlaub record the treatment with *x*-rays of 16 cases of plantar warts. In many of the patients there were multiple lesions. Fifteen of the patients were cured. There was not a single recurrence. The number of treatments ranged from one to seven. Invariably the pain disappeared in from two to four days subsequent to the first treatment. The dose was H1⅓ S. D., unfiltered, every three or four weeks. Some of the patients remained under observation for six years. Wise successfully treated 7 cases without recurrences. He employed intensive doses, unfiltered, at intervals of one month.

Fig. 186.—A plantar wart before treatment.

Fig. 187.—Same as Fig. 186, after one intensive *x*-ray treatment.

The plantar wart has been a nuisance to dermatologists. These painful lesions have been exceedingly recalcitrant to other methods of treatment and not infrequently they have to be dealt with surgically.

The results with roentgen therapy in this condition have been so good that the author regards such treatment as the method of election. Sixty patients affected with verruca plantaris have been treated. In many instances there were multiple lesions. The final result in 30 cases is unknown. Of the remaining 30 cases, 20 were cured, 4 improved and in 6 there was no improvement. Six patients were cured in one treatment.

Technic.—Each lesion, when the lesions are multiple, should be separately treated. The opening in the lead shield should fit the lesion exactly; normal skin must not be included in the field of radiation. The horny layer should be cut away as much as possible with a sharp razor. If caustics have been applied or if the lesions are inflamed, it is advisable to postpone the treatment for a week or two. Many lesions will disappear as a result of th[illegible]tration of a

single intensive dose of unfiltered radiation (H1 or H1¼ S. D.). A week or two subsequent to the treatment the patient is likely to notice that the lesion is a little more sensitive than usual; then sensitiveness to pressure disappears entirely and, frequently, the lesion disappears in from three to six weeks. If there is no improvement and there has been no *x*-ray reaction by the fourth week, a second and larger dose is given (H1¼ or H1½ S. D.). At times it is safe to give as much as H2 and even H2½ S. D. unfiltered. These large doses are not administered unless the hyperkeratosis, of which the lesion is mainly composed, is very marked. The thickened horny layer acting as a filter prevents an excessive amount of radiation from reaching the underlying tissue (derma).

If a lesion does not disappear as a result of three or four intensive or hyperintensive doses no benefit and perhaps serious injury will result if the treatment is continued. If a radiodermatitis occurs it does so under the thick horny layer and it is likely to be overlooked. In this event repetition of treatment may be followed by a third-degree radiodermatitis. The danger signals are swelling or a pushing outward of the lesion due to underlying inflammation, increased and persistent sensitiveness to pressure and inflammation of the surrounding, unirradiated skin. The author has seen the insidious development of a third degree reaction under one of these lesions due to the too persistent treatment of an unusually recalcitrant lesion.

Filtration.—With a few exceptions all the cases were treated with unfiltered radiation. The exceptions were unusually large and thick lesions. It is possible that better average results might be obtained with filtered radiation. More experience will be required before this question can be definitely decided. Both types of radiation seemed to give the same results in lesions of average size. Lesions of this size that failed to respond to unfiltered radiation did not improve when treated with filtered radiation. Very large and thick lesions seemed to do better with filtered rays.

The very thick horny layer acts as a filter and permits the application of a rather large dose of unfiltered radiation without injury to the derma. With filtered radiation there is less absorption by the horny layer, hence the amount received by the derma as compared to that received at the surface is greater than with unfiltered radiation. Theoretically, therefore, the therapeutic effect of filtered radiation should be superior to that of unfiltered radiation, the dose being the same in both instances (from H1 to H2 S. D.).

The author prefers unfiltered radiation as a routine because: Of economy in time; in all but unusual cases the effect seems to be the same for filtered as for unfiltered radiation; if, inadvertently, the filter should be omitted and the dose is estimated as though a filter were being used, the effect might be very unpleasant if not serious. This may seem to be a foolish suggestion, but the author has known

this technical error to happen on four different occasions to four different operators all of whom were careful, conscientious men and two of whom were experienced roentgenologists.

Radium.—Personal experience with radium in the treatment of verruca plantaris is limited to 10 cases. Insofar as can be determined from such limited experience, the results are the same as with *x*-rays as, indeed, should be the case. Few literary references of consequence dealing with this aspect of radium therapy have been encountered. Bissell reports cures of both plantar warts and corns with radium. In 2 of the author's cases lesions that failed to improve under roentgenization were equally resistant to both beta rays and gamma rays. Small lesions may be treated with penetrating beta rays, especially if most of the horny layer is first removed, a screen of $\frac{1}{4}$ mm. to 1 mm. of aluminium being sufficient. Most, if not all, of the beta rays will be absorbed by the horny layer of very thick lesions. In such instances it is presumably the gamma rays that prove effective whether or not a heavy filter is used. Either flat or tubular applicators may be used. What has been said relative to the use of *x*-rays in this affection will apply, also, to the use of radium. For further details the reader is referred to the chapters on Radium Technic and General Therapeutic Considerations.

CORNU.

Hard corns are recalcitrant to both *x*-rays and radium. It usually requires from two to four intensive or hyperintensive treatments to effect a clinical cure. It is not possible to establish a clinical cure in all cases. The lesions occasionally recur. The technic of application and the precautions to be taken are the same as in the treatment of verruca vulgaris and verruca plantaris and need not be repeated here.

Soft corns, situated between the toes, usually undergo complete involution as a result of one or two intensive treatments. The best results obtained by the author have been with tubular radium applicators. The tube is prepared as described in the radium treatment for verruca vulgaris of the nostril (*supra*). No filter other than the glass wall of the tube is required. If a small flat applicator is used it is advisable to use a screen that will absorb the "soft" beta rays.

KERATOSES.

Under this heading will be discussed Senile Keratosis, Arsenical Keratosis, *X*-ray Keratosis and Miscellaneous Keratoses.

Senile Keratosis.—(*Senile Wart; Seborrheic Wart or Keratosis*).—Sutton divides senile keratosis into three types—keratoid, nevoid and verrucous. The keratoid type, clinically, is a gray to brown squama which may be dry and firmly adherent or which may be waxy

and less firmly attached to the rete. The lesion consists of hyperkeratosis or parakeratosis with atrophy and perhaps degeneration of the rete. The nevoid type is a yellow to dark brown, smooth, elevated lesion, characterized entirely by acanthosis. The horny layer is very little if at all thickened. The verrucous type is as the name implies, papillomatous and is characterized by acanthosis and hyperkeratosis or parakeratosis.

Any type of senile keratosis is a potentially dangerous lesion (epithelioma). It is advisable, therefore, to deal with these lesions radically or leave them alone. They will usually involute when irradiated but they are likely to be stubborn.

FIG. 188.—Senile or seborrheic keratosis with cutaneous horn.

FIG. 189.—Same as Fig. 188 showing exfoliation after one intensive treatment.

For the keratoid variety it is preferable to first remove the horny layer with a curette and then apply an intensive or subintensive application of unfiltered beta rays. This one treatment will usually suffice for a clinical cure. Recurrences are uncommon. Several months after the treatment it is usually impossible to detect the site of the former lesion, but in some persons there may be depigmentation, atrophy and rarely telangiectasia. As a rule, the cosmetic result is better than with carbonic acid snow and other caustic measures, but this is not always so.

The nevoid and verrucous types may be treated successfully with either x-rays or the beta or gamma rays of radium. Occasionally a lesion will disappear as a result of one intensive or hyperintensive

treatment, but very often several such treatments are necessary. Some lesions will not disappear without applying a quantity sufficient to produce a severe reaction. Recurrences are rather common. The author prefers to curette these lesions. This can be done quickly and painlessly under ethyl chloride local anesthesia. It is only necessary to remove the epidermis; a scar, therefore, does not result. After the curettage a suberythema dose of *x*-rays or radium is applied. By this method one treatment usually suffices to effect a permanent cure and, as a rule, the result is perfect from a cosmetic standpoint, although in some persons, the site of the former lesion may be a little atrophic or a little ligher or darker than the surrounding skin.

A very important point is to be certain of the diagnosis—certain that the lesion is not an early epithelioma. If there is any doubt, it is advisable to consider the lesion an epithelioma and treat it as such (see Chapter XXXIII).

Senile keratoses occur on all parts of the body but mainly on the face, dorsal surfaces of the hands and the trunk. They occasionally develop at the mucocutaneous junctures when they are prone to form cutaneous horns. Keratoses are fairly common on the mucous membranes of the lip. The lesions on the lip are especially dangerous and should be dealt with radically—removal of horny layer and a dose of "soft" beta rays sufficient to effect a second-degree reaction (excoriation) or, if preferred, an erythema dose of *x*-rays. In the case of a cutaneous horn, the horn should be removed before the lesion is irradiated. A thick and very adherent keratosis sometimes occupies the entire lower lip. The removal from a mucous membrane of such an adherent horny layer is difficult and at times impossible without destroying considerable tissue. In such instances one or two intensive or hyperintensive *x*-ray or gamma-ray treatments, limited strictly to the lesion, will usually be followed by a disappearance of the hyperkeratosis. If the cure is not complete the entire lip should then be exposed to an erythema dose of "soft" beta rays.

As a rule, it is advisable to allow an eighth of an inch of normal skin around the lesion to remain in the field of radiation. For further technical details the reader is referred to the chapters on Technic, and General Therapeutic Considerations.

Arsenical Keratoses.—Individual keratoses due to arsenic and also those due to tar, paraffin, etc., will usually disappear under the influence of *x*-rays or radium. The author has not yet treated the so-called arsenical palm with either of these agents.

X-ray Keratoses.—The beta rays of radium will almost always cause the disappearance of the painful and dangerous keratoses that develop in "*x*-ray skin." The author has had the extreme pleasure and gratification of removing in this manner *x*-ray keratoses from the hands of a number of pioneer roentgenologists. The lesions may also be cured with *x*-rays and gamma rays, but the beta rays give much better results.

McDonnell, who had scattered *x*-ray keratoses over the dorsal surface of one hand, reports the disappearance of the lesions as a result of twenty-one fractional treatments, the radiation being allowed to spread over the entire hand. Sequeira, commenting on McDonnell's result, cautions against the possible remote effects. The author agrees with this admonition, but he considers that it is wise and safe to employ radium beta rays for this purpose if a proper technic is used. In fact such treatment, when comparing the results with other methods, constitutes the method of election in most cases.

Sequeira (1908) was probably the first to treat such lesions with the *x*-rays; Tousey (1915) seems to have been the first to try radium. The lesions were on his own hands. Four months later Abbe reported the cure of a number of cases. Abbe also reports the cure with radium of several *x*-ray epitheliomata. Degrais and Bellot have cured *x*-ray keratoses and ulcers with radium. The author has clinically cured one epithelioma of this kind with *x*-rays and two with radium. One of the patients has remained under observation for five years and there has been no recurrence.

In his article Abbe calls this phenomenon an apparent paradox. The words were well chosen; the paradox is apparent and not real. The development of a keratosis in skin that has been injured by *x*-rays is at least partly if not entirely idiosyncratic. It is exactly the same thing that happens in xeroderma pigmentosum, sailor's skin, farmer's skin, etc. The point is that the skin has been altered by *x*-rays, actinic rays, or other physical and chemical agents. The cells are compelled to adapt themselves to the new environment and in doing so they develop new characteristics and power of independent growth. As far as is known a preëpitheliomatous keratosis is fundamentally the same whether due to *x*-rays, sunlight or other causes. If *x*-rays and radium rays can cure keratoses and early cutaneous epithelioma due indirectly to actinic rays, and they can do so, there is no good reason why they should not be equally efficacious in similar lesions caused indirectly by *x*-rays or radium rays. It must not be assumed from this argument that radium or *x*-rays are advocated in all cases of *x*-ray keratosis. As a matter of fact the author is opposed to the use of either *x*-rays or gamma rays in these cases. The derma and even the subcutaneous tissue is usually sclerotic in these cases and large doses of either gamma rays or *x*-rays will add to the injury and pave the way for additional trouble. In the early cases it is necessary to destroy only the epidermis and the papillary body and this can be done with "soft" beta rays.

Theoretically, even this treatment is far from ideal. However, the fact that there is no other method that gives as good results and the fact that no untoward results have been noted for as much as six years, warrants the use of this treatment until a better method is evolved.

Technic. The lesion should be soaked in a hot solution of carbonate of soda [illegible] for an hour or two and then trimmed as much as possible with a very sharp knife. While the lesion is soft an unfiltered flat radium applicator is kept in contact with the lesion for a length of time sufficient for an erythema dose. In these cases it is preferable to treat the surrounding skin to the very edge of the lesion. Small lesions will disappear after one treatment. Larger lesions may require two or three treatments at monthly intervals. Cancer lesions may be treated to better advantage with similar applicators [illegible] chapters on Radium Technic and General Therapeutic Considerations.

LEUKOPLAKIA

The first recorded instance of the treatment of leukoplakia with x-rays [illegible] in the treatment of cancer cases by Pusey in 1904. In treating carcinoma of the mucosa of the right cheek Pusey noticed that the associated leukoplakia, which involved the entire cheek, totally disappeared. The patient lived only a few months but during this time there was no recurrence. Improvement but not a cure was obtained in one case of very extensive leukoplakia and a clinical cure in another patient who had a patch of leukoplakia the size of a fifty-cent piece. In this case a moderate radiodermatitis was produced. In 1911 Pusey, in discussing the treatment of leukoplakia, states: "I have succeeded in curing a good many of them by the use of x-rays." There are very few reports in the literature dealing with x-ray treatment of this affection. The general opinion appears to be that x-rays are of very little service.

Freudenthal, [illegible], treated a case of extensive leukoplakia with radium. The ulceration and pain disappeared but the leukoplakia remained. Wickham and Degrais treated several cases, some of which were cured; others were improved. Pinch, Boggs, Newcomet, Bayet, Finzi, Knox and others report cases that have been improved or cured. Knox has obtained good results with both x-rays and radium. Abbe finds radium a positive cure for leukoplakia.

The author has been disappointed with both x-rays and radium in the treatment of this affection. X-rays were tried several years ago on a number of cases but the results were so poor and the difficulty of proper application so great, that the work was discontinued. During the past few years efforts have been confined to radium. Small patches have often disappeared as a result of one application of beta rays—an exposure sufficient to effect a second degree reaction. Many of these patients have been free of recurrence for three years. No improvement has resulted unless the treatment has caused a reaction consisting of edema and erosion. Not a single case of extensive leukoplakia was cured. In a few instances the lesion disappeared only to return in a few weeks or months. Even some of the small lesions failed to disappear, and if they did disappear, many of them recurred immediately.

In one patient, after several intensive treatments, a slow-growing epithelioma developed on the lateral surface of the tongue near its base. In another patient a very rapidly growing epithelioma appeared in a patch of leukoplakia after two intensive treatments. Schamberg reports the development of epithelioma in a patch of leukoplakia one year subsequent to *x*-ray treatment.

It would be unfair to say that the epithelioma in these cases was caused by the treatment, although such a possibility must be considered. Leukoplakia is neither syphilis nor cancer. It is a keratosis and dyskeratosis of unknown etiology in which epithelioma very frequently develops—epithelioma of the metastatic type. Therefore leukoplakia must be considered one of the most dangerous forerunners of cancer. The affection is exceedingly recalcitrant to all forms of treatment, which makes the uncertain results of radium all the more disappointing and discouraging.

Leukoplakia is a dangerous preëpitheliomatous lesion. Any form of treatment that might stimulate or irritate the cells is prohibited. If it is treated at all it should be dealt with radically. The affection is superficial, characterized by acanthosis, dyskeratosis and hyperkeratosis, with more or less evidence of inflammation in the papillary body. Occasionally the affection is verrucous or papillomatous. For these reasons the author prefers to use the penetrating beta rays and a dose sufficient to effect erosion of the entire epidermis and destruction of the papillary body. Many of the authors quoted supra advise filtered *x*-rays or heavily filtered radium persistently applied over a period of several months. Such advice seems to be contrary to the indications and requirements. The author advises beta rays in preference to *x*-rays or gamma rays. The "soft" beta rays should be eliminated by a screen of $\frac{1}{10}$ mm. of aluminium or the filtration equivalent in some other material. If the leukoplakia is thick (verrucous) 1 mm. of aluminium should be used. If one or two applications (hyperintensive or ultraintensive) fail to effect a clinical cure some other method, such as the electric cautery, should be advised. The author is of the opinion that a prompt recurrence should not be treated with radium.

At the present moment the author prefers to remain non-committal regarding the advisability of treating leukoplakia with radium in preference to other methods. Small patches can be cured with radium but they can be cured with greater certainty (although with more discomfort) by means of the galvano-cautery. Extensive leukoplakia is almost incurable with any method of treatment. In any event a guarded prognosis should be given and no promises made.

KRAUROSIS VULVÆ.

Kraurosis is included in this group of diseases because its symptomatology often includes leukoplakia of the vulvæ or a condition that greatly resembles leukoplakia.

The author has treated 3 cases of kraurosis vulvæ with subintensive doses of *x*-rays. The diagnosis in each instance was confirmed by dermatological colleagues. One patient, besides atrophy, leukoplakia and intense itching, had an epithelioma. The epithelioma was excised before irradiation. After three *x*-ray treatments the itching ceased. There was no change in the leukoplakia. The subsequent history is unknown. Another patient with leukoplakia and intensive itching, failed to improve after several subintensive treatments. The affection in both cases was of long duration. In the third patient (recently treated) the duration was two years. The mucosa was thick, it was glazed in places and milky white in other places. There was a tenacious discharge and intense itching. After the second intensive treatment the itching, thickening and discharge disappeared. The leukoplakia had changed from white to an almost imperceptible gray. The patient has remained free of subsequent symptoms for six months. Runge treated 2 cases of kraurosis vulvæ with *x*-rays without improvement in either case.

In treating kraurosis vulvæ the fact that it is a forerunner of cancer must be kept in mind. It would seem advisable to discontinue treatment if the symptoms are not relieved as a result of two or three months of treatment. Also it would seem preferable to employ intensive rather than fractional treatment. The technic of applying *x*-rays and radium to this part of the body will be found in the chapter on Pruritus.

KERATOSIS FOLLICULARIS.

(Darier's Disease.)

The author had 1 case of Darier's disease the lesions of which disappeared as a result of roentgenization. There were a few scattered areas of the affection distributed over the body surface. The eruption in some areas underwent complete involution subsequent to a single suberythema dose. Other areas required two or three such treatments. Nothing is known relative to the subsequent history of the patient. It was not a severe case; the duration was only a few months. The clinical diagnosis was confirmed microscopically.

Lieberthal recorded the first case of Darier's disease ever treated with *x*-rays (1904). Ritter cured a very extensive case. Stout saw marked improvement in 1 patient, even the untreated lesions underwent involution. Mook obtained good results in 4 cases. Scheer obtained marked improvement in 1 patient and G. H. Fox, Engman and Mook, and Bulkley saw considerable improvement in 1 case. H. Fox has been disappointed with results obtained with *x*-rays in this affection.

With such limited experience it is not advisable to outline a technic. Generalized cases will probably do well under fractional *x*-ray treatment, while localized patches can be treated with either fractional or intensive applications of *x*-rays or radium.

XERODERMA PIGMENTOSUM.

The keratoses and the epitheliomata occurring in this affection may be cured with *x*-rays or radium, especially with the beta rays of radium. This statement is made with the understanding that the epitheliomata, if of the prickle-cell type, are in the early stages of evolution and involve only the skin (epitheliomata in this affection may be of the basal-cell or of the prickle-cell type). The technic of application will be found in this chapter under the heading of Keratosis and in the chapter on Epithelioma. The author has treated only 2 cases and in both instances the epitheliomata, which were of the basal-cell variety, were more stubborn than is usual for this type of epithelioma. The keratoses disappeared but many of them recurred.

Perrin and Dupeyrac (1906) were the first to record the use of *x*-rays in this disease. They were able to make the warty lesions and malignant tumors disappear in their 1 case. Jamieson, and Allen have reported the disappearance of keratoses and epithelioma following irradiation.

Of course *x*-ray or radium treatment does not modify the prognosis of this dreadful and hopeless disease, but such treatment may give the poor little patients temporary comfort.

ACANTHOSIS NIGRICANS.

Wise reports a case of acanthosis nigricans of the juvenile type, occurring in a young woman. She presented typical and well-pronounced lesions implicating practically the entire body, with rugose and papillary growths in the axillæ and groins. A series of fractional roentgen-ray treatments, extending over a period of five months, resulted in complete involution of the lesions, so that her skin became normal in appearance and texture. The author saw this patient both before and after treatment and he can confirm the diagnosis and the completeness of the clinical cure. The eruption followed the decapsulation of the kidneys. Cognizance is taken of the fact that the juvenile variety of this disease occasionally undergoes spontaneous involution. All that can be said in this connection is that the eruption had lasted for a long time and had not been influenced by other remedies. Involution began with the institution of roentgen therapy and it was rapid, continuous and complete.

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CHAPTER XXXI.

NEVI AND CONGENITAL KERATODERMATA.[1]

THE diseases or conditions discussed in this chapter are:

1. Angioma
    - Nevus Flammeus.
    - Nevus Vasculosus.
    - Angioma Cavernosum.
2. Lymphangioma
    - Lymphangioma Cavernosum.
    - Lymphangiectodes.
    - Angiolymphangioma.
    - Angiokeratoma.
3. Nevus Pigmentosus.
4. Nevus Pilosus.
5. Nevus Verrucosus.
6. Adenoma Sebaceum.
7. Ichthyosis and Allied Conditions.
8. Telangiectasia (Spider Nevus, etc.).

X-rays and radium have a limited field of usefulness in this group of dermatoses when the group is considered as a whole. The results of radium therapy in some types of angioma are, however, very striking.

ANGIOMA.

The results obtained with *x*-rays and radium in this nevus, will depend upon the particular type of angioma treated and the method of applying the radiation. There is some confusion relative to the classification and nomenclature of the various clinical types of angioma. For convenience angioma may be divided into three clinical types:

1. Nevus flammeus (port-wine mark).
2. Nevus vasculosus (strawberry mark).
3. Angioma cavernosum (cavernous angioma).

These clinical types will be separately considered.

Port-wine Mark.—Port-wine marks are usually located on the face and neck and vary in size and color. They may be no larger than a dime or they may occupy one entire side of the face and neck. They may be pale red (pink) dark red or bluish red. They are never elevated above the niveau of the skin. Occasionally angiomatous tumors may develop in a port-wine mark.

The *x*-rays and probably the gamma rays of radium are not of the slightest service in this affection. The author has seen an *x*-ray

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

technician with a port-wine mark of the anterior surface of the left forearm and back of the left hand. For several years these parts received daily exposures of unfiltered radiation while making fluoroscopic examinations. Finally, the skin became atrophic, keratoses appeared, and two of the keratoses developed into metastatic epithelioma. The nevus was still present and, according to the patient's statement, had not changed in color since he was a boy. The author has tried roentgen therapy in cases of port-wine mark without noting any alteration in color. Of course, if the treatment is carried to destruction of the upper part of the derma, the result may be improvement in the nevus but at the possible and even probable expense of serious *x*-ray sequelæ later in life.

Not much more can be said relative to the beta rays of radium. Hartigan reports the eradication of a port-wine mark which involved most of the left side of the face. Thirty-nine applications were made with an unscreened radium applicator. Superficial ulceration occurred after most of the treatments. Pinch was unable to obtain satisfactory results in this type of nevus with radium after several months of treatment. He used a screen of $\frac{1}{10}$ mm. of aluminium. He advises caution in these cases because of the possibility of sequelæ. Jones failed to obtain good results with very lightly screened radium. Simpson (unpublished) states that he has cured pale port-wine marks with the toile type of radium applicator. Wickham and Degrais have caused the disappearance of port-wine marks but they admit atrophy and telangiectasia as sequelæ, and also aver that this type of nevus is exceedingly stubborn. The author has failed to modify port-wine marks with radium without effecting a sharp beta-ray reaction. It is his opinion that neither *x*-rays nor radium should be employed in this type of nevus. Much better results can be obtained with ultraviolet rays and without the risk of permanent injury to the skin.

Nevus Vasculosus (*Strawberry Mark*).—In this type of angioma the lesion is red and it is elevated to a greater or lesser degree above the surface of the skin. The lesions involve only the superficial vessels and vary in size from a pinhead to an adult hand. They are soft in consistence and tend to enlarge for a few years after which they may undergo involution, which may be spontaneous or which may be due to ulceration or traumatism. They occur perhaps most frequently on the face but they are seen on nearly all parts of the body.

X-rays and gamma rays are capable of curing this type of angioma but the effect of beta rays of radium is so superior that *x*-rays and gamma rays are contra-indicated.

The results of beta-ray therapy in nevus vasculosus are so striking, so perfect, that they may be placed among the most notable achievements of radium therapy in the treatment of cutaneous affections.

In small lesions in infants one or two treatments will often suffice for com[illegible] [illegible]ppearance of the nevus. Larger and thicker lesions may [illegible] treatments.

A flat applicator is to be preferred. In all but the extremely thin lesions it is advisable to use a screen of from $\frac{1}{10}$ to $\frac{1}{4}$ mm. of aluminium or the filtration equivalent in some other material. It is permissible to cause a slight erythema, but this is not necessary or advisable. Suberythema doses administered once every three or four weeks is the usual method. The lesions should be closely shielded.

Nevus vasculosus often occurs on the scalp, eyelids and in the eyebrows. The hair follicles extend for a considerable distance below the vascular new growth. The nevus is extremely susceptible to the influence of the beta rays. The "soft" and "medium" beta rays are for the most part absorbed before they reach the hair bulbs. For these reasons it is possible, with lightly screened radium and suberythema doses, to effect complete involution of the nevus without causing defluvium.

FIG. 190.—A large strawberry mark on the forearm.

FIG. 191.—Same as Fig. 190, after radium treatment.

Unless one has had considerable experience, it is not advisable to attempt the treatment of a nevus of large dimensions with tubular applicators as the effect is likely to be very uneven. If the growth happens to be linear, as may be the case on the eyelid, a tubular applicator may be of service. It is not necessary to protect the eye

when treating a lesion of this kind on the eyelid, etc. If the lesion is carefully shielded with lead foil, the lids kept closed, and only the "soft" or "medium" beta rays utilized, there will not be sufficient radiation absorbed by the eye to result in harm. This statement is based on experience.

Hartigan, Jones, Finch, Simpson, Wickham and Degrais, Newcomet, Finzi and many others have testified to the efficacy of radium in the treatment of nevus vasculosus. The photographs published by some of these authors, especially those presented by Wickham and Degrais, are exceedingly striking. The first articles written on this subject were from the pens of Danlos, Hartigan, Follard, Eckstein, Strasmann and Rehns (quoted by Wickham and Degrais).

Angioma Cavernosum.—In this type of angioma the deep vessels, especially the veins, are involved. The lesions consist of soft tumors which vary in size from a pea to a silver dollar. Occasionally they are much larger and may even involve the greater part of the face. The tumor may project well above the surface of the skin or the elevation may be only slight. The overlying skin may be normal; often it is the site of nevus vasculosus. Not infrequently lesions are encountered on the tongue, mucous surfaces of the cheeks, the labia, etc. Cases are seen where the entire thickness of the cheek is involved in the growth. Cavernous angiomata are found on nearly all parts of the body. The sites of predilection are perhaps the face and scalp. This type of nevus is exceedingly common in infants and children, less common in adults. The explanation is that many such lesions, especially when small, undergo a slow spontaneous involution or are cured as a result of accidental traumatism or ulceration.

The fact that these lesions may spontaneously involute (the author has seen such involution) makes it unwise to employ any method of treatment that might eventually terminate in objectionable sequelæ. Spontaneous cure is likely to be incomplete, exceedingly slow and it is often followed by scarring. The deeper lesions are likely to remain throughout life. For these reasons treatment is indicated, but it should be associated with caution and good judgment.

Small lesions can be totally eradicated by both *x*-rays and radium. Extensive and deep-seated lesions can be either eradicated or greatly improved. There is no doubt but that beta rays are by far more efficacious than are *x*-rays or gamma rays when the lesion has a depth of not more than two or three centimeters. For deeper lesions there seems to be little if any difference between the effect obtained with *x*-rays or gamma rays.

All the authors so far mentioned in this chapter have obtained magnificent results with radium. Pusey and others have demonstrated excellent results with the *x*-rays. The author prefers and advises radium in the treatment of angioma cavernosum. It is the method of election for this condition.

Flat applicators are suitable for most cases, and the applicator

uld be screened with from $\frac{1}{10}$ to 1 mm. of aluminium, depending on the depth of the abnormal tissue. The dose should be just a le less than the amount required for a first-degree reaction and it

FIG. 192.—Nevus vasculosis of the upper right eyelid.

FIG. 193.—Same as Fig. 192, after two radium treatments.

FIG. 194.—An extensive cavernous angioma involving the entire thickness of the cheek and the buccal mucosa.

FIG. 195.—Same as Fig. 194, after over a year of subintensive, monthly radium treatments. Photograph was taken about a year after the last treatment.

may be repeated every three or four weeks. If the skin is involved, the redness disappears in two or three treatments but it may require from four to twelve treatments to cause the complete disappearance of the underlying tumor. The number of treatments required, omitting technical errors, will vary with the size and depth of the lesion. Lesions in adults are more recalcitrant than are those in children. The author has encountered deep-seated cavernous nevi in adolescents and adults that were so stubborn that it was necessary to discontinue treatment in order to prevent undue injury to the skin.

In some locations, such as the cheeks and vulva, the lesion may be cross-fired to advantage. Cavernous nevi situated on the scalp, when treated with *x*-rays or radium, may be followed by permanent alopecia. However, the author has been surprised in a number of instances to see a good growth of hair subsequent to the complete eradication of large cavernous angiomata on the scalp of infants.

The results sometimes obtained in this type of nevus are astonishing. Photographs published by Simpson and especially by Wickham and Degrais depict results that are not less than marvelous. The author, several years ago, treated a baby who had a facial cavernous angioma of such extent, irregularity and depth, as to constitute a monstrosity. Treatment over a period of fourteen months with beta and gamma rays completely eradicated the nevus without visible injury to the skin. Before a photograph could be obtained, however, the child died of pneumonia contracted during the epidemic of influenza at the close of the War.

For additional details relative to filtration, administration of radiation to convex surfaces and inaccessible locations, cross-fire, protection of unaffected parts, etc., the reader is referred to the chapters on Radium Technic, Filtered *X*-rays and General Therapeutic Considerations. Suffice it to say here that the most important desideratum is to eradicate the nevus without causing the undesirable sequelæ that are so likely to be the result of strenuous treatment with *x*-ray or radium. If it is determined that a given angioma will not disappear without an amount of treatment that may seriously injure the skin, it is advisable to discontinue the use of radiation. In recalcitrant cases it is often impossible to obtain complete involution without some visible atrophy. In fact it is difficult in such instances to ascertain how much disfigurement is due to the former nevus and how much is due to the treatment. While it may be impossible in some cases to avoid slight wrinkling of the skin it is possible to avoid telangiectasia and especially the more serious keratoses. The operator should strive for good cosmetic results in all cases. Almost every roentgenologist or radiologist can show a photograph of a few excellent results. We do not hear so much about the one or two patients who had disfiguring sequelæ. It is better to fail in a number of instances without doing harm than it is to cure several cases and have one patient with disfiguring and even dangerous sequelæ. The tumors should be closely shielded; the normal skin must not be included in the field of radiation.

LYMPHANGIOMA.

The author has not been able to modify the lesions of lymphangioma cavernosum in infants and children with either *x*-rays or radium. Only 3 cases were treated and it is possible that a wider experience might lead to the development of a technic that will give more encouraging results. Gordon cured 1 case of lymphangioma of the tongue with radium. Abbe cured 2 cases.

Several cases of lymphangiectodes (lymphangioma circumscriptum) have been successfully treated with both *x*-rays and beta rays of radium, but they have not responded as quickly as have the vascular nevi. The lesions were situated both on the skin and the buccal mucosa.

Abbe cured 6 cases with beta rays. McEwen reports improvement in 1 case treated with *x*-rays. Hartzell, Knowles, Ormsby, and Engman and Mook have cured cases with *x*-rays. In 1 of Engman and Mook's patients the lesion occupied most of one side of the abdomen. Simpson reports the cure of a very large lesion with radium.

The author has had better results with penetrating beta rays than with *x*-rays. In all instances considerable treatment was required. The technic of application and precautions to be taken are the same as with vascular nevi and need not be repeated here.

Two cases of angiolymphangioma or hemangioma were successfully treated with radium. Dominici, Cheron and Barbarin cured an extensive case of hemolymphangioma with radium. The tumor occupied the right side of the neck and extended to the chest.

NEVUS PIGMENTOSUS.

Wickham and Degrais, Abbe and others have removed pigmented nevi with beta rays of radium, and Pusey and others have accomplished the same results with *x*-rays.

The author has given both agents a fair trial in nevus pigmentosus. There was no noteworthy amelioration unless the treatments were of sufficient strength to effect a sharp reaction and the author is opposed to such treatment for pigmented nevi.

X-rays and radium may be employed to depilate the hair in nevus pigmentosus et pilosus, and then some other method can be used to destroy the nevus (see under Nevus Pilosus).

It has been said that moles will disappear under the influence of radium treatment. The author tried both beta rays and gamma rays without result. The doses used were within the amount necessary to evoke a first-degree reaction.

Moles and pigmented nevi are endothelial or epithelial growths, benign in character it is true, but potentially dangerous. They should be totally eradicated or left alone. Their total eradication with radium means the possibility of sequelæ that may be also potentially dangerous.

The author is of the opinion that *x*-rays and radium are not indicated the trea [illegible] nevus pigmentosus.

NEVUS PILOSUS.

A growth of hair in a restricted area of skin that is usually free of hair, may or may not be associated with pigmentation of the skin. In other words we may have a nevus pilosus or a nevus pilosus et pigmentosus.

In the latter there is a difference of opinion as to whether the hair should be removed with radiation or with electrolysis. Many dermatologists aver that the electrolytic needle should never be inserted into a mole or any kind of a pigmented nevus. Others claim that there is more danger associated with irradiation than with electrolysis. The author is unable to decide this important point; he has not seen any serious consequences from either method.

It is possible to effect a permanent loss of hair without more than almost imperceptible wrinkling or atrophy of the skin. The amount of wrinkling will depend, if correct technic can be assumed, largely upon idiosyncratic tendencies and, also, upon the location. However, the work is associated with considerable difficulty. The author has never been able to depilate the hair from a hairy nevus situated on the face, with a single *x*-ray treatment without producing a first-degree reaction. The reader is advised not to attempt such treatment. It is not good policy to belittle a mild first-degree reaction on exposed parts of the body. There are a number of persons who had a hairy nevus on the face and who now have an area of telangiectasia. The hair could have been destroyed or removed in some other way, the telangiectasia is more disfiguring and in many instances it cannot be removed.

The affected part should be properly shielded and fractional doses of *x*-rays administered at intervals of five days until defluvium occurs. After this it is necessary to administer a suberythema dose once a month until the hair bulbs have been destroyed—this will vary from six to twelve months. For further technical details relative to the production of *x*-ray defluvium see chapter on Hypertrichosis, Tinea Tonsurans and Sycosis Vulgaris.

ICHTHYOSIS AND CONGENITAL KERATODERMATA.

The thickened horny layer of ichthyosis vulgaris, ichthyosis hystrix, ichthyosiform erythroderma, etc., will often shed after one intensive or several fractional doses of *x*-rays or radium. The skin then has a normal appearance. The benefit is of little value, however, as in all cases so far treated there has been a recurrence within a few weeks.

The same may be said regarding verrucous nevi and congenital keratoderma palmaris et plantaris. In all cases treated by the author the benefit has been but temporary. A permanent effect might be obtained with doses sufficient to produce a severe reaction, but such treatment is not warranted. Dohi and Mine caused the disappearance of the thickened horny layer in cases of palmar and plantar keratoderma with bo *x*-rays and radium. The original article is not available and noth

is said in the abstract relative to permanency. Allen treated cases of verrucous nevus and while he was able to improve the lesions, the results did not warrant advocacy of the method. Wickham and Degrais report permanent cures in cases of linear verrucous nevus and angiokeratoma. Wise treated 2 cases of linear verrucous nevus with unfiltered x-rays, but obtained no benefit.

Fig. 196.—Ichthyosis before treatment.

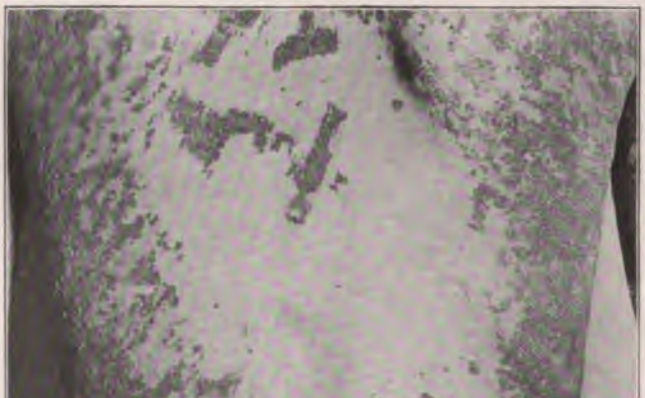

Fig. 197.—Same as Fig. 196, showing exfoliation of thickened horny layer after one intensive x-ray application. Result is not permanent.

Monilethrix.—Ciarrocchi claims to have cured one case of monilethrix with *x*-rays. Low noted a disappearance of the associated keratosis pilaris and more normal hairs than before the *x*-ray treatment, but the patient was not cured. Guszmann failed to obtain any improvement. The author depilated 2 scalps of patients afflicted with monilethrix, with the same technic as used in tinea tonsurans. When the hair returned the beaded hairs appeared to be as numerous as before the treatment. The associated keratosis pilaris disappeared for a time but it, too, returned.

There has been no personal experience with *x*-rays or radium in the treatment of keratosis pilaris of the body nor has any reference been found in the literature other than those quoted supra.

Adenoma Sebaceum.—The author treated 2 cases of adenoma sebaceum with beta rays of radium and 1 case with unfiltered *x*-rays. There was no improvement. Ormsby reports a similar experience.

Telangiectasia.—Telangiectasis may be congenital or acquired. These conditions, in the author's experience, cannot be eradicated with *x*-rays or radium without effecting unwarranted reactions. These statements apply, also, to the so-called spider nevus. Axmann, however, has successfully removed telangiectasia with radium. Much better results have been obtained with ultraviolet rays (see Chapter XV).

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CHAPTER XXXII.

BENIGN NEW GROWTHS.[1]

Many diseases classified pathologically as benign new growths will be found discussed in other chapters. Some of the affections in this chapter are granulomata. The grouping used by the author is largely one of convenience—in other words it is a convenient grouping rather than a scientific classification. The entities discussed in this chapter are:

1. Keloid.
2. Dermatitis Papillaris Capillitii.
3. Rhinoscleroma.
4. Molluscum Contagiosum.
5. Xanthoma.
6. Fibroma; Neuroma; Myoma.
7. Lipoma.
8. Multiple Benign Cystic Epithelioma and Allied Conditions.
9. Leprosy.
10. Syphilis.
11. Ulcerating Granuloma of the Pudenda.

KELOID.

Ullmann, Hahn, Albers-Schönberg, Taylor, Harris, Crocker, Morton, Pusey, Edwards and Allen were the first to report the usefulness of *x*-rays in the treatment of keloids and hypertrophic scars. Ullmann noted the improvement in scar tissue while treating lupus vulgaris and suggested that the *x*-rays be tried in keloidal tissue from other causes.

Williams was the first to employ radium for this purpose. Wickham and Degrais a few months later, reported the successful treatment of a number of cases.

Today there is a pretty general agreement that irradiation alone in most cases and combined with surgery in some cases, constitutes the best method of combating keloid and hypertrophic scar. It is the only method of treatment that insures against recurrence.

Clinical Types.—Dermatologists recognize two types of keloid: true spontaneous or idiopathic keloid and keloid that develops in a scar. The latter are called hypertrophic scars. Inasmuch as the effect of irradiation is the same in both types it is not necessary to discuss them separately.

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

Keloids may range from a slight thickening of scar tissue to great tumors the size of an adult male fist and even larger. They may consist of a well-defined tumor arising from a tiny scar or they may be spread over very large surfaces as is so frequently seen in keloids following burns. There may be keloidal bands which cause disfigurement by displacing the soft parts such as the mouth, eyelids, etc.

Fig. 198.—A very dense and long-standing keloid resulting from an electric burn.

Fig. 199.—Same as Fig. 198, after ten subintensive, filtered x-ray treatments.

Keloids may be red, brown, or the color of normal skin. Usually they are telangiectatic. At times they are pedunculated. They may be sensitive to pressure. Keloids that have existed for a long time, and keloids that have evolved very slowly are likely to be firm, even hard. Recent keloids and those of comparatively rapid growth are much less hard to the palpating finger.

These facts are of importance to the roentgenologist. Young, small, rapidly-growing keloids involute rapidly when irradiated. Larger growths, older growths and those that evolve very slowly may be recalcitrant. The other manifestations, such as erythema, pain and telangiectasia, will be discussed later.

Comparison of Irradiation with other Methods.—Surgery does not give good results because recurrence is common and the recurrence is likely to be much worse than the original growth. Carbon dioxide snow has many advocates, especially for small keloids, but here too recurrences are common. Electrolysis, cauterization and other measures may also give good results in selected cases. However, any method of treatment that produces a wound, *i. e.*, that is traumatic, is likely to be followed by a keloid that is larger than the one removed. Irradiation is the only known method of treatment that will positively preclude recurrence. The cosmetic result is better as a rule after irradiation than after other forms of treatment but this is not always so.

FIG. 200.—Keloid following operation.

FIG. 201.—Same as Fig. 200, after six subintensive, unfiltered *x*-ray treatments.

Prophylactic Treatment.—Keloids occur only in persons who are idiosyncratic, *i. e.*, persons who have a keloidal tendency. Years ago the author was of the opinion that the irradiation of a healed wound occurring in an idiosyncratic person would prevent the subsequent development of keloid. It has, however, been necessary to modify this opinion. That a keloid may develop in tissue that has been extensively irradiated is shown by the following cases:

CASE 18.—A young woman had an epithelioma (basal-cell type) situated in the nasolabial fold. The tumor was given four intensive *x*-ray treatments without favorable results. It was then removed with the curette and acid

nitrate of mercury was applied to the floor of the wound for fifteen minutes. The resulting crust did not fall off for two months at which time there appeared a rapidly growing keloid, the diagnosis of which was confirmed by a biopsy. The keloid disappeared as a result of two suberythema doses of *x*-rays. There has been no recurrence of either the epithelioma or of the keloid during a period of five years.

CASE 19.—An attempt had been made to remove a mole from the chin of a woman of middle age. After three intensive treatments the lesion was excised. The excision was followed by a keloid which also was excised. A recurrence took place. The new keloid was treated successfully with *x*-rays. There has been no recurrence.

CASE 20.—A young woman had received *x*-ray treatment in Germany for lupus vulgaris of the left cheek. When seen by the author there was no evidence of lupus but there were numerous *x*-ray sequelæ—atrophy, telangiectasia and keratoses. Part of the scar was keloidal.

Newcomet reports the development of a large keloid following the very vigorous application of radium to a port-wine mark.

While it must be admitted that irradiation is not a true prophylactic against the development of keloid, it is nevertheless of great value for this purpose if employed at the proper time. When removing keloids by excision Pfahler recommends the administration of a suberythema dose just prior to the operation and additional treatment at the slightest evidence of recurrence. Preliminary treatment may be of value when a keloid is already present, but it is doubtful if such preliminary treatment would prevent the evolution of a keloid subsequent to trauma occurring in an idiosyncratic person. In fact the author doubts the value of preliminary irradiation even when a keloid is to be excised excepting for the purpose of promoting the involution of keloidal tissues that may escape the knife.

Pfahler scores a very good point when he advocates the early diagnosis and irradiation of keloid. If surgeons would recognize hypertrophy of scar tissue as soon as clinically manifest and have the area irradiated at once, it would probably not require more than two or three suberythema applications to prevent further development and to cause the disappearance of the infiltration.

It is doubtful if a single treatment with *x*-rays or radium, subsequent to traumatism but prior to clinical thickening of the scar, would prove of value in preventing keloid. Furthermore, there is no certainty that a keloid will return after excision, or that it will develop after traumatism in an idiosyncratic person. The best prophylactic procedure, therefore, seems to be to await the first manifestation of keloidal evolution. One, two or three suberythema doses of either *x*-rays or radium will then, in all probability prevent further development and cause involution of the clinical thickening of the scar.

Combined Treatment.—Large keloids cannot be removed by irradiation without danger of leaving undesirable and even serious sequelæ.

Such keloids should be removed surgically and irradiation employed as a prophylactic. As pointed out by Pfahler, it is not necessary to make a wide excision; endeavor to obtain a good cosmetic result; it does not matter if keloidal tissue is left *in situ*. When the growth is situated in an inaccessible location it may be possible to do no more than to cut away the bulk of the mass, the wound being allowed to granulate. As mentioned supra Pfahler recommends a preliminary suberythema dose. After the operation, if keloidal tissue has been left *in situ*, monthly suberythema exposures are made for three or four months. If the excision has been complete the patient should be kept under observation and irradiation delayed until there is clinical evidence of thickening, when a few suberythema or semi-intensive applications will usually suffice for the desired result.

Sequelæ.—It is uncommon to have a well-developed keloid involute without leaving a cosmetic defect. This defect may consist of a scar, more or less atrophy and perhaps telangiectasia. We are not discussing *x*-ray and radium sequelæ. It should be appreciated that these defects are caused by the disease—not by the treatment. Of course, irradiation can effect the same sequelæ—atrophy, telangiectasia, depigmentation, etc. *X*-ray telangiectasia occurs more often in keloid than in any other affection.

Results.—The results of irradiation in most types of keloid are exceedingly gratifying. Small keloids (split pea to dime) will disappear in from one to three or four subintensive treatments with little if any disfigurement, especially if they have existed for only a few months. One must not expect to have large and older keloids disappear without leaving some scarring or atrophy and perhaps a few dilated vessels. Furthermore, such keloids require considerably more treatment. Growths the size of a silver dollar, or the palm of a hand, may require as many as eight, ten or twelve suberythema treatments over a period of a year or more. This, of course, will depend partly upon the thickness of the growth. A widespread but not thick keloid, one, for instance, that occupies the entire chest, will flatten to the niveau of the skin when properly irradiated. On the other hand, quarter to palm-sized tumors that are from ½ to 1 inch or more in thickness may not disappear under an amount of radiation that is within the limits of safety. Such tumors may be treated surgically and irradiation employed as a prophylactic.

Keloidal bands, irregular keloidal masses scattered over an extensive surface, and old, hard keloids, even when only slightly elevated, are very recalcitrant and good judgment and considerable caution is required in order to avoid disfiguring and dangerous sequelæ.

The erythema that is associated with some keloids may or may not disappear during the treatment. Usually it does not disappear until several months after the last treatment. Pain, if present, usually disappears after the first few treatments.

After involution of a keloid, subsequent to irradiation, the skin or

the scar is usually soft and pliable. Contractions (ectropion, etc.) are therefore prevented.

Technic.—(*X-rays*).—It is absolutely essential that the normal skin to the very edge of the lesion be shielded with lead foil. Fractional treatment or semi-intensive treatment may be given. The author prefers subintensive treatment every four to six weeks. An erythema is to be avoided if possible. The tumor will involute more rapidly under larger doses but the end-result may be undesirable (sequelæ). It is difficult to set the maximum number of such treatments in obstinate cases. Twelve treatments might be considered as the limit. If the keloid has not disappeared as a result of such treatment it probably will not improve with a continuation of the treatment. The exact dose will depend upon the age of the patient and the location of the keloid. A lesion on the back of an adult male brunette will often tolerate H1¼ S. D., unfiltered (H2½ S. D. filtered) without effecting an erythema. A similar tumor situated on the face of a young girl or a child may not tolerate more than one-half of this dose. (See chapter on Idiosyncrasy.) During the course of treatment the skin should be observed frequently and carefully for evidence of injury.

Unfiltered radiation may be employed for prophylactic treatment, for small keloids that are not of long duration, and for widespread hypertrophic scars that are only slightly elevated. If, however, the tissue is thick, it is advisable to filter with 3 mm. of aluminium.

Radium.—In reviewing the work of Abbe, Simpson and others, one is led to believe that radium is superior to *x*-rays in the treatment of keloid. Knox, who had the opportunity of treating many keloidal scars during the War, does not mention any difference in the efficacy of *x*-rays and radium. His results in the use of both of these agents as an aid to cosmetic surgery of the face following gunshot wounds are nothing less than remarkable. The author has failed to note any difference in efficacy between *x*-rays and gamma rays. Hypertrophic scars or keloids, when the pathological tissue is less than a centimeter in thickness, seems to do better under beta-ray treatment.

Radium is more easily applied to lesions in locations where it would be difficult to administer *x*-rays. Also in long, linear keloids and lesions of unusual shape. In some instances it is possible to cross-fire with a combination of *x*-rays and radium. Knox used this method to good advantage in the extensive and deep-seated keloidal masses developing in the cheeks. Radium was placed in the mouth and *x*-rays were applied to the external surface of the cheek.

Flat radium applicators are usually employed when treating keloid with radium. In all cases the "soft" beta rays should be eliminated by suitable screening. If the lesion is more than 1 cm. thick only gamma rays should be used. Tubular applicators are of service in linear lesions. The glass wall of the tube will provide sufficient filtration for these lesions. In general the advice given relative to the *x*-ray treatment of keloid holds for radium when used for the same

purpose. For further technical details the reader is referred to the chapters on Radium Technic and General Therapeutic Considerations.

Wickham and Degrais report a remarkable case of keloid of the mucous membrane of the upper lip which they cured with radium. The case is remarkable because keloid very rarely develops in the mucous membranes.

FIG. 202.—Dermatitis papillaris capillitii. Before treatment.

FIG. 203.—Same as Fig. 202, after *x*-ray treatment. There was considerable depigmentation which has been hidden by the stain mentioned in Chapter XV.

DERMATITIS PAPILLARIS CAPILLITII.

It is remarkable how few references there are in the literature relative to the treatment of this disease with *x*-rays. Most of the books on roentgen therapy and radium therapy fail to even mention the disease. On the other hand practically all of the dermatological

text-books recommend the use of the *x*-rays, stating that the progress of the disease can be checked and the keloidal scars reduced in size. G. H. Fox was apparently the first to use *x*-rays in this affection while Wickham and Degrais were the first to treat the disease with radium.

Dermatitis papillaris capillitii (acne keloid) is usually situated on the back of the neck—the nucha. In the early stage of evolution the eruption consists of extremely hard, pinhead-sized papules which are situated in the follicular orifices. There are occasional pustules. The hairs are twisted, dry and break readily. At first the elementary lesions are discrete, later they become closely aggregated and finally they coalesce into keloidal masses that may range in size from a split pea to a walnut and even the size of an adult male fist. The evolution is slow; it is usually several years before the keloidal lesions become very large.

If the disease is irradiated during the papular stage it may be aborted and permanently eradicated as a result of from one to three suberythema applications at monthly intervals. The back of the neck in adults will usually tolerate H1 S. D., unfiltered, without provoking an erythema. The same results will follow fractional and semi-intensive treatments. It is not necessary nor advisable to employ filtered *x*-rays.

After the advent of the keloidal stage the disease is more recalcitrant, the degree of resistance depending upon the duration and size of the keloidal tumors. In this stage filtered radiation is indicated and the technic does not differ from that given for keloids. Large tumors may be excised or reduced in size by some other method and radiation applied to effect complete involution and to eradicate the disease.

In the early stage it is possible to preserve most if not all of the hairs. In the later stage it is usually necessary to push irradiation to the point of permanent alopecia. In this connection it should be recalled that the disease itself destroys most of the hair follicles.

The disease may occupy the entire nucha and may involve the lateral surfaces of the neck. This constitutes a large convex surface which requires two exposures, one for each side, the oblique rays being allowed to overlap in the center. All parts not affected by the disease should be shielded, special attention being given to the scalp hair.

Radium.—The results of radium treatment are the same as those obtained with the *x*-rays. In the early stage "hard" beta rays are employed, the "soft" beta rays being eliminated by means of a screen of from $\frac{1}{10}$ to $\frac{1}{4}$ mm. of aluminium. Thick keloidal masses should be treated with gamma rays.

The points to be emphasized, in the treatment of this affection are:

1. Early diagnosis and early institution of roentgen therapy or radium therapy.
2. Avoid even first-degree reactions.
3. In order to avoid long-continued treatment with the possibility of undesirable sequelæ, it is often advisable to first treat large kelodial

masses with some surgical method and then irradiate for the purpose of thoroughly eradicating the disease.

The author has never seen or heard of a recurrence after a clinical cure. Irradiation gives better results than can be obtained with any other method. Such treatment may be depended upon to cure every case. It is, therefore, the method of election.

Before treating a case of this disease with either *x*-rays or radium the beginner should read the portion of this chapter dealing with Keloids, also the chapters on General Therapeutic Considerations, Idiosyncrasy, Radium Technic, and *X*-ray Technic, both Filtered and Unfiltered.

RHINOSCLEROMA.

This annoying and heretofore intractable disease can be permanently cured with *x*-rays or radium. In the early granulomatous stage the affection yields quickly to treatment. In the later stage, when the nose is greatly enlarged and the tissue is stone-like in consistence, the disease is more recalcitrant.

Ranzi, in 1904, appears to have been the first to establish a literary record of the *x*-ray treatment of this disease. This author, however, refers to 2 cases that were treated by Fittig. Pollitzer presented a cured case before the New York Academy of Medicine, Section on Laryngology, in October, 1906. Ballin reported a cured case in 1907, the *x*-rays having been applied by Stern. Lustgarten presented the patient before the New York Dermatological Society (April, 1907) at which time he told of the good results obtained in additional cases treated by Stern. Freund, Kahler, Schein, von Navratil, Smith, Lieberthal, Ruediger-Rydygier, and others have reported successful results with *x*-rays in the treatment of single examples of this disease.

Wunderlich, of Guatemala, has had considerable experience with the *x*-ray treatment of rhinoscleroma. He presented 3 cured cases before the Pan-American Medical Congress in 1908 and later reported 14 additional cures. Quinonez also reported a number of cures at the same Congress.

Kahler was apparently the first to treat rhinoscleroma with radium (1905). Guttman reports great improvement in a case treated with radium, the treatment having been administered by I. Lavine. Boggs reports the cure of a case with radium.

The author has cured 3 cases of rhinoscleroma with *x*-rays. In 1 instance the disease was diagnosed in a very early stage. The lesion consisted of a firm but not hard tumor occupying the right nostril. The patient was cured as a result of three monthly treatments (courtesy of Dr. Remer). In 2 patients the disease was well developed, the nose being greatly enlarged, and the disease involved the upper lip. The affected parts were as hard as rock and the nasal passage was completely occluded. Both patients were cured, the parts returning to normal, as a result of five monthly treatments in

one case and eight such treatments in the other. In each instance the diagnosis was confirmed by biopsy. Two additional cases were treated with considerable improvement, but the patients failed to continue the treatment or to remain under observation.

There have been no reports of recurrence subsequent to a complete clinical cure. The result appears to be permanent. Irradiation, alone, will cure the affection. It is unnecessary, in the majority of cases, to institute surgical methods.

Technic.—It is advisable to have the patient carefully examined by a competent rhinologist in order to ascertain the extent of involvement. Usually the disease begins in the mucous membrane of the anterior nares. It may then involve the entire nose and the upper lip. Rarely the disease may develop in the larynx as was the case in one of Lustgarten's patients who was treated by Stern. After the first *x*-ray treatment the dyspnea became so great that it was necessary to open both the larynx and trachea. When the report was made the tumor had disappeared.

Fig. 204.—Rhinoscleroma. (Courtesy of Dr. M. J. Wunderlich.)

Fig. 205.—Same as Fig. 204, after *x*-ray treatment. (Courtesy of Dr. M. J. Wunderlich.)

As a rule, then, the treatment can be confined to the nose, and upper lip if the latter is involved.

The aim should be to cure the disease without leaving sequelæ and in the majority of cases this is possible. Only filtered radiation should be employed (3 mm. Al.). The dose should be within the amount required to effect an erythema—from H1½ to H2 S. D., depending upon the age of the patient and the color of the skin. Applications are made at intervals of one month, *i. e.*, intensive filtered treatment. The entire face, with the exception of the nose, is shielded. An exposure

is then made to each side of the nose with the target at right angles to the plane of the lateral surface of the nose. The rays are permitted to overlap at the bridge of the nose. A separate exposure may be necessary for the upper lip if this part is involved.

If the nares are patulous a tubular radium applicator covered with a screen of lead foil may be placed inside the nose, first in one nostril and then in the other. The length of exposure will depend naturally upon the amount of radium element in the tube. A 30 mg. tube screened with $\frac{1}{2}$ mm. of lead may be left in the nose for two or three hours in addition to the *x*-ray treatment applied to the external surface of the nose. If the nares are occluded, the radium (tube or plaque) suitably screened, may be placed against the roof of the mouth. Care should be taken to cover the lead screen with thick rubber in order to prevent a secondary-ray reaction. These cross-fire treatments, in the absence of reaction, may be administered at intervals of one month.

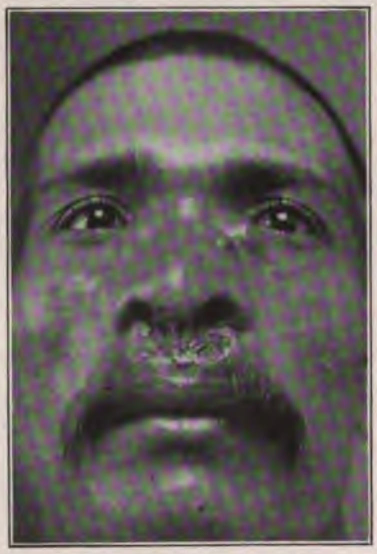

FIG. 206. — Rhinoscleroma. (Courtesy of Dr. M. J. Wunderlich.)

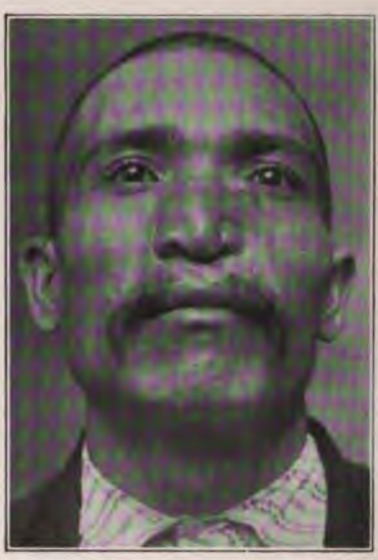

FIG. 207.—Same as Fig. 206, after *x*-ray treatment. (Courtesy of Dr. M. J. Wunderlich.)

Gamma rays of radium may be used instead of *x*-rays for the external irradiation. The result should be the same.

MOLLUSCUM CONTAGIOSUM.

Finzi states that radium therapy has been successful in the treatment of molluscum contagiosum. The author has used the *x*-rays experimentally in this affection; the lesions failed to involute as a

result of an erythema dose. It is the author's opinion that irradiation is not indicated in this disease, the lesions of which are readily amenable to other forms of treatment.

XANTHOMA.

The author applied suberythema doses of *x*-rays to several lesions in one case of xanthoma tuberosum, one of xanthoma planum, and one of xanthoma diabeticorum. In the first patient treated (xanthoma tuberosum) there was some involution of the irradiated lesions after the first suberythema treatment. There was no improvement after the second and third exposures. The lesions in the other patients did not improve at all. Beta rays of radium were applied to the lesions in one case of xanthelasma (xanthoma palpebrarum). There was no improvement as a result of three suberythema applications of "hard" beta rays. Applications of a strength sufficient to effect a reaction were not tried; such treatment is not justified.

Gottheil tried *x*-ray treatment in a case of xanthoma tuberosum multiplex with negative results. Brown obtained benefit in two cases after a reaction had been produced. Lustgarten reports temporary improvement with *x*-rays. Allen, Stern, Evans and other early workers report good results in the various types of xanthoma. It should be realized that these reports were made years ago when roentgenologists did not appreciate the advisability of avoiding *x*-ray sequelæ. Finzi states that good results have been obtained with radium. Pinch treated 7 cases with radium; 5 patients were cured; 2 patients were improved.

FIBROMA, NEUROMA, MYOMA, LIPOMA.

Schültz, Bondet and others state that *x*-rays will sometimes cause a diminution in the size of cutaneous lipomata, fibromata, and allied conditions. The necessity of effecting a reaction is admitted. In the author's hands the results have not been favorable.

As is well known, uterine fibromata and myomata undergo complete involution when irradiated. It is, however, the consensus of opinion that the result is caused by the effect of the radiation on the ovaries and not by direct action on the tumor.

Wise treated a hazel-nut-sized tumor of fibroma molluscum (von Recklinghausen's disease). Three unfiltered, suberythema doses were applied at intervals of four weeks. There was no alteration in the size or consistence of the tumor (verbal communication).

BENIGN EPITHELIOMA.

The author has tried *x*-ray treatment in cases of benign cystic epithelioma, tricho-epithelioma, syringoma and allied conditions. It is

possible to cause complete involution of the lesions but to do so it is usually necessary to administer from four to eight suberythema doses or several months of fractional or semi-fractional treatment.

These eruptions consist, as a rule, of a large number of small, discrete lesions scattered over the center of the face or, in some instances, distributed over large areas of the body surface. It is a time-consuming task to treat each individual lesion separately. If this is not done the dose must be within that required for an erythema otherwise there is the possibility of injury to rather extensive areas of normal skin. It might be a good plan to treat the individual lesions with the "hard" beta rays of radium. While such a procedure is time-consuming, the radium can be applied by the patient under the supervision of the dermatologist.

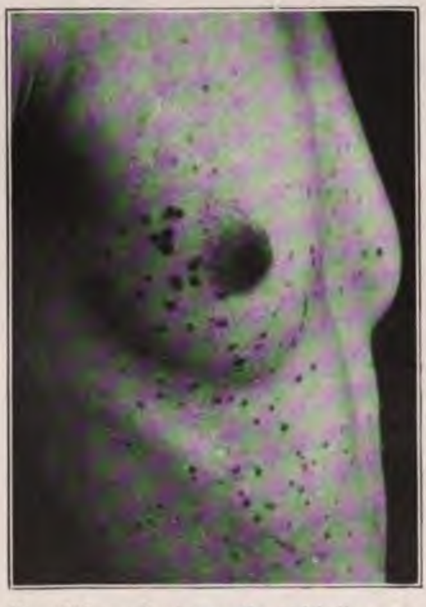

FIG. 208. — Benign cystic epithelioma or syringoma before x-ray treatment.

FIG. 209.—Same as Fig. 208, after x-ray treatment.

Mitsuto caused complete disappearance of an eruption of syringoma situated on the chest with four x-ray treatments, each application consisting of one-third of an erythema dose. Ormsby cured a case of syringoma with fractional x-ray treatment. Hodara reports improvement in a case of syringocystadenoma.

LEPROSY.

Heiser treated 1 leprosy patient with x-rays. All clinical evidence of the disease disappeared but lepra bacilli could be found in scrapings

from the nasal mucosa. Allen, Oulmann, Morris, and Wilkinson have noted improvement in lesions that have been subjected to irradiation. G. H. Fox has seen some patients improve and others get worse under irradiation.

The author has administered *x*-ray treatment to 8 cases of leprosy of different clinical types. In no case was there more than partial involution of the lesions. Irradiation appears to be of little value in this disease.

SYPHILIS.

The older text-books and journals contain numerous references to the use of *x*-rays in syphilis. Cowen, for instance, exposed the entire body of a patient affected with tertiary syphilis to radiation. According to Cowen's article the results were remarkable. Of course irradiation is not of the slightest service in the treatment of syphilis and is only employed in this disease when there has been a mistake in diagnosis. Syphilitic lesions, even ulcerated lesions, are very recalcitrant to irradiation. The author has never seen a syphilitic lesion disappear as a result of such treatment. In former years it was thought that involution could be hastened in this manner. Most cutaneous lesions of syphilis undergo spontaneous involution in time. This fact together with the fact that involution was often slow under the older methods of antisyphilitic treatment, probably explains the reason for the opinions of some roentgenologists of former years.

Gangosa.—No record can be found relating to the use of radium or *x*-rays in the treatment of gangosa. Mink and McLean, who have made a careful study of the disease, suggest irradiation but they have not tried such treatment nor have they heard of its having been employed for this purpose.

Ulcerating Granuloma of the Pudenda.—Macleod has employed roentgen therapy with success in this affection. Most of the English text-books on dermatology recommend roentgenization. Several articles dealing exhaustively with this disease have been consulted but practically nothing has been found to prove the usefulness or uselessness of irradiation in this disease.

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CHAPTER XXXIII

MALIGNANT NEW GROWTHS.[1]

THE cutaneous new growths discussed in this chapter are:

1. Basal-cell Epithelioma.
2. Prickle-cell Epithelioma.
3. Secondary Metastatic Epithelioma.
4. Paget's Disease.
5. Sarcoma
    - Round-cell Sarcoma.
    - Spindle-cell Sarcoma.
    - Giant-cell Sarcoma.
    - Melanoma.
    - Kaposi's Sarcoma.
    - Fibrosarcoma.

BASAL-CELL EPITHELIOMA.

The first basal-cell epithelioma to be treated with roentgen-rays was demonstrated before the Swedish Medical Society on December 18, 1899, by Stenbeck of Stockholm. At the same meeting Sjögren showed a similar case. In the former instance, however, the epithelioma had disappeared, while in the latter the demonstration occurred before a clinical cure had been effected. These reports were immediately followed by others and very soon the literature was swamped with articles on this subject. The earliest reports in Europe were from the pens of Sederholm, Scholtz, Taylor, Ferguson and Sequeira. In the United States the earliest workers were Johnson and Merrill, Pusey, Williams, Beck, Rinehart, Morton, Hopkins, Allen and Duncan.

Statistics.—In the past fifteen years a voluminous literature dealing with roentgen therapy in basal-cell epithelioma has been developed. But before reviewing and commenting on the more important articles the author desires to tabulate and discuss the results obtained in 644 unselected cases of basal-cell epithelioma which were treated between the years 1910 and 1919 inclusive. The patients were treated in accordance with modern technic. The statistics in this chapter were compiled by Miss Katherine Sullivan.

Clinical Cures.—Of the 644 patients, 180 were not seen after the first treatment, so that the result could not be recorded. This leaves a total of 464 patients who remained under observation for at least a few months. Of these 464 cases there were [illegible] clinical cures or [illegible] per cent. Thirty-three patients, 7 per cent, improved, and in 7 cases, 1 per cent,

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[1] For explanation of terms used in this chapter in regard to dosage see Chapter XIX.

the lesions were not even benefited. When it is considered that the cases were not selected and that at least one-half the failures were due to the patients' inability to have second or third treatments at proper intervals, or that the case was deemed practically hopeless when treatment was instituted, 91 per cent. seems very satisfactory. As an illustration, several of the patients received a single treatment which did not suffice to effect a clinical cure. Then, on account of illness, old age, stormy weather, or other reasons, they did not return for the second treatment until the lesion was worse than it was at the beginning. In other instances the lesions were very deep and indurated, even involving the articulations or the entire orbit, and had received previous roentgen-ray treatment. If one could omit such cases the percentage of cures would be in the neighborhood of 93 or 98 instead of 91.

FIG. 210.—Ulcero-nodular basal-cell epithelioma.

Preëpitheliomatous lesions are not included in this study. In other

, every case was distinctly an epithelioma from a clinical stand- and the lesions varied in size from a split-pea to several inches in ter, in duration from a few months to several years and they developed as a nodule or evolved from some preëpitheliomatous . In only a few cases was the diagnosis confirmed by the micro- , but in most instances the patients were seen by dermatological res who agreed with the diagnosis. It would be senseless to

1.—Same as Fig. 210, after two hyperintensive *x*-ray treatments. No recurrence in nine years.

y every case of basal-cell epithelioma because it is one of the t conditions for the dermatologist to recognize.

urrences.—Of the 421 clinically cured cases, 139 failed to remain observation for six months. As will be seen later, most of the ences take place within one year so that patients that are not ved for at least six months are of little statistical value so far as rns the question of recurrence. We have, then, a total of 282

clinically cured cases that were observed for periods of from six months to nine or more years. In this series of 282 cases there were 36 relapses —13 per cent., leaving a total of possible permanent cures of 87 per cent.

A more critical analysis reveals that 2 cases were observed for nine years or more with no relapse—100 per cent. possible permanent cures. Three cases remained under observation eight years with 1 relapse—66⅔ per cent. Twenty-two cases remained under observation for seven years with 3 relapses—86 per cent. Twenty cases remained under observation for six years with 3 relapses—85 per cent. Twenty-four patients were observed for five years with 3 relapses —75 per cent. Thirty-one patients remained under observation for four years.

Fig. 212.—Serpiginous basal-cell epithelioma on a convex surface.

Fig. 213.—Same as Fig. 212, after two hyperintensive x-ray treatments. No recurrence in five years.

In this series there were 5 relapses, leaving 84 per cent of probable permanent cures. Thirty-six cases were followed for three years in which there were 8 recurrences—83 per cent. cures. Of the two year cases (about two years) there were 51 with 5 relapses—91 per cent. cures. Fifty-six cases were observed for about one year with 6 recurrences—89 per cent. cures. Thirty-seven cases were followed for six months—2 relapses—95 per cent. cures. Finally, 139 cases were observed for from one to five months. In this series there were no relapses. Table IX summarizes these statistics and enables the reader to grasp them at a glance

TABLE IX.—CURES AND RELAPSES ARRANGED ACCORDING TO THE NUMBER OF YEARS UNDER OBSERVATION.

Period of observation.	Number of cases.	Number of relapses.	Percentage of cures.
9 years	2	..	100 per cent.
8 "	3	1	66⅔ "
7 "	22	3	86 "
6 "	20	3	85 "
5 "	24	3	87 "
4 "	31	5	84 "
3 "	36	8	78 "
2 "	51	5	91 "
1 year	56	6	89 "
6 months	37	2	95 "
Less than 6 months	139	..	100 "

Late Recurrence.—It is interesting to note that a majority of the recurrences manifested themselves in less than a year. As indicated in Table X, there were 36 cases in which a relapse occurred, 21 (58 per cent.) of which occurred in the first year. Nine were noted in the second year, 5 in the third year and 1 in the fourth year.

TABLE X.—RELAPSES IN RELATION TO TIME OF OCCURRENCE.

Relapse at end of.	Relapse treated with.	Result.	Second relapse end of.	Second relapse treated with.	Result.
6 months	X-rays	Cured			
6 months	X-rays	Cured			
6 months	X-rays	Cured			
6 months	Radium	Cured			
6 months	Curettage and caustic	Cured	Several months	Untreated	Failure.
6 months	X-rays	Cured	4 months	Radium	Cured.
1 year	X-rays	Failure			
1 year	Excision	Cured			
1 year	X-rays	Cured			
1 year	X-rays	Cured	2 years	X-rays	Cured.
1 year	Curettage and *x*-rays	Cured	1 year	Radium	Failure.
1 year	Radium	Cured	1 year	Radium, curettage and caustic	Cured.
1 year	X-rays	Cured	1 year	X-rays	Cured.
1 year	Excision	Failure			
1 year	X-rays and radium	Cured			
1 year	X-rays and radium	Cured	1 year	X-rays	?
1 year	X-rays	Cured	6 months	X-rays	?
1 year	X-rays	Cured			
1 year	Curettage and *x*-rays	Cured	3 months	Curettage and caustic	Cured.
1 year	X-rays	Cured	1 year	X-rays	Failure.
1 year	X-rays	Cured	1 year	X-rays	Cured.
2 years	X-rays	Cured	4 years	Curettage and radium	Cured.
2 years					
2 years					
2 years	Curettage and *x*-rays	Cured	1 year	Curettage and *x*-rays	Cured.
2 years	Curettage and *x*-rays	Cured			
2 years	Untreated	Failure			
2 years	X-rays	Cured	1½ years	Cross-fire *x*-rays	Failure
2 years	Untreated	Failure			
2 years	X-rays	Cured	2 years	X-rays	Cured.
3 years	X-rays and radium	Cured			
3 years	X-rays	Cured			
3 years	Curettage and *x*-rays	Cured	1 year	Curettage and caustic (twice)	Cured.
3 years	X-rays	Failure			
3 years	Curettage and *x*-rays	Failure			
4 years	X-rays	?			

The fact that one relapse was noted as late as the fourth year, makes it advisable to warn the patient of this possibility. That there is not much likelihood of a récidive after the fourth year, in properly treated cases,

the fact that 102 patients were observed for periods of from four to nine years and yet there was only 1 relapse that manifested itself four years after treatment.

Treatment of Recurrences.—A study of Table X will show that 27 of the 36 relapses were treated again with the roentgen rays, and that 23 recovered; in 1 case the result was unknown, while 3 failed to improve. Two of the recurrences were cured with radium; 1 by surgical excision; 1 with the Sherwell operation (curettage and acid nitrate of mercury); 1 with excision and 4 cases were not treated. It will be noted that 12 cases relapsed a second time within a year after the second recovery. Three of these lesions again disappeared under further *x*-ray treatment; 1 under radium; 1 under radium and Sherwell operation; 2 responded to the Sherwell operation; 1 remained untreated; in 2, treated with *x*-rays, the result was unknown; 1 treated with *x*-rays resulted in a failure as did also one treated with radium. To recapitulate, 23 out of 27 primary relapses responded immediately to the roentgen rays, in 1 the result was unknown and 3 failed to get well. One of the 12 secondary recurrences was untreated; in 2 treated with *x*-rays the result was unknown; 1 treated with *x*-rays resulted in failure as did also 1 treated with radium. Seven responded to various types of treatment. From the foregoing it will be seen that a relapse should not cause unnecessary alarm.

FIG. 214.—Ulcerating basal-cell epithelioma of the inner canthus.

FIG. 215.—Same as Fig. 214, after one hyperintensive *x*-ray treatment. No recurrence in eight years.

Effect of Previous Treatment.—An attempt was made to ascertain if previous treatment altered the susceptibility of the lesion to intensive roentgenization The result of this study is shown in Tables X and XI. There were 421 clinically

TABLE XI.—CURES, FAILURES AND RELAPSES IN RELATION TO PREVIOUS TREATMENT.

	No. cases.	No previous treatment	Excision.	Cauterization.	Curettage	X-rays or radium.	Electrolysis.	Caustics.
Cures	....	56%	6%	.7%	7%	12%	3%	15%
	286	160	16	2	21	34	10	43
Failures	....	33%	9%	....	....	39%	....	18%
	33	11	3	....	....	13	....	6
Relapses	....	23%	14%	....	8%	28%	8%	18%
	21	5	3	....	2	6	2	4

cured cases of which the previous treatment was known in only 286. Seven cases are omitted from the 40 failures because the previous treatment could not be ascertained and 15 cases are omitted from the 36 relapses for the same reason. The most noteworthy feature here is that 39 per cent. of the failures were in cases that had been treated previously with *x*-rays or radium, usually the former in small doses over long periods of time. The percentages are obtained from the total number of cases as shown in the first column with the exception of the relapses. Here the "cured and not followed" cases were first deducted.

TABLE XII.—RESULTS IN RELATION TO NUMBER OF TREATMENTS.

Number of treatments.	Number of cases.	Cures.	Clinical cures not followed.	Relapses.	Failures.
1	208	42% 196	5% 24	3 % 6	3% 12
2	173	35% 163	5% 23	10 % 15	2% 10
3	39	7% 36	2% 8	25% 7	.6% 3
4	15	3% 12	2% 7	60% 3	.6% 3
5	10	1% 6	2% 1	80% 4	.8% 4
6	7	.6% 3	....	33⅓% 1	.8% 4
7	2	.2% 1	....	....	.2% 1
8	4	.4% 2	....	....	.4% 2
9	2	.2% 1	....	....	.2% 1
10	1	.2% 1			

Results in Relation to Number of Treatments.—Table XII shows the results in relation to the number of treatments given. Only the cases with known end-results are recorded—461 cases. It will be seen that 196 cases, 42 per cent. of the total of 461, were cured as a result of one treatment Or, considering only the cured cases (421), 46 per cent. were cured in one treatment, 38 per cent. in two treatments, 8 per cent. in three treatments, etc It is interesting to note that 7 obstinate cases received as many as six intensive treatments with 3 cures, 4 failures and 1 relapse. The percentage of cures is high as far as the second treatment. It would seem from this, as might be assumed, that if a lesion is not favorably influenced by two or three hyperintensive treatments, the chances of producing the desired result with the roentgen rays is lessened. The percentages are obtained from the number of cases treated, with the exception of the relapses. Here the "cured and not followed" cases are first deducted from the total number of cases.

TABLE XIII.—FILTERED VERSUS UNFILTERED X-RAYS.

	Number of cases.	Cures.	Cures not followed.	Relapses.	Failures.
Unfiltered . .	409	94% 388	13% 52	6 % 22	6% 21
Filtered . . .	52	65% 33	2% 11	66⅔% 14	34% 19

The study outlined in Table XIII does not give the true comparative value of filtered and unfiltered radiation because, as a rule, the lesions that received filtered treatments were more deeply seated, larger and more indurated than were the lesions treated without a filter. The percentage of relapses are obtained after deducting the "cured and not followed" cases from the total number of cures. The other percentages are taken from the total number of cures.

Number of Treatments Required.—Some idea of the difference in malignancy or obstinancy of the lesions may be obtained by a glance at Table XIV which shows the number of treatments necessary in individual cases both with filtered and unfiltered radiation.

Fig. 216.—A pigmented serpiginous basal-cell (?) epithelioma.

Fig. 217.—Same as Fig. 216 after four hyperintensive doses. There was a recurrence in one and a half years which disappeared with one radium application. There has been no recurrence for three years.

The key to Table XIV is as follows:

In the first vertical column there were 200 out of a total of 409 unfiltered cases that received only one treatment. Of these 200 cases, 193 were cures and 7 failed to improve. Therefore 47 per cent. of the 409 unfiltered cases were "cured" in one treatment. The total 499 is obtained by adding the various unfiltered totals in the first horizontal column. In the second vertical column we find that 8 out of 62 filtered cases received one treatment. Three of these patients were cured; in othes words, 6 per cent. of the total number of filtered cases were cured in one treatment. The failure percentage is also taken from the total 52, but for the relapses the "cured and not followed" case is deducted from the 3 cures and the percentage obtained from the remaining 2 cases that were "cured" and that remained under observation.

Effects of Curettage.—After eliminating the cases with unknown results, there was a total of 275 lesions that were curetted immediately preceding the application of the roentgen rays. Table XV gives a comparison between the results obtained in cases that were and those that were not curetted.

TABLE XV.—COMPARISON OF RESULTS IN CURETTED AND NON-CURETTED CASES.

	Number of cases.	Cured.	Cured, not followed.	Relapses.	Failures.
Curetted	275	92% 254	8% 21	9% 17	8% 21
Not curetted	186	89% 167	25% 42	15% 19	11% 19

TABLE XIV.—FILTERED AND UNFILTERED CASES IN RELATION TO NUMBER OF TREATMENTS.

	1 treatment.		2 treatments.		3 treatments.		4 treatments.		5 treatments.		6 treatments.		7 treatments.		8 treatments.		9 treatments.		10 treatments.	
	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.	Un-filt.	Filt.
No. cases	200	8	154	19	31	8	13	2	4	6	4	3	..	2	..	4	2	..	1	
	47%	6%	36%	26%	7%	11%	2%	3%	.5%	7%	.5%	2%	..	2%	..	2%	.2%	..	.2%	
Cures .	193	3	149	14	30	6	10	2	2	4	2	1	..	1	..	2	1	..	1	
	3%	5%	7%	63%	16%	100%	50%	100%	....	100%	50%	...								
Relapses	5	1	10	5	4	3	2	1	....	4	1									
	2%	9%	1%	9%	.2%	3%	7%	...	.5%	3%	.5%	2%	..	2%	..	2%	.2%			
Failures	7	5	5	5	1	2	3	...	2	2	2	2	..	1	..	2	1			
Cures not	11%	33⅓%	11%	42%	16%	50%	60%	50%	50%											
followed	23	1	17	6	5	3	6	1	1											

TABLE XVI.—CURETTED AND NON-CURETTED CASES IN RELATION TO NUMBER OF TREATMENTS

	1 treatment.		2 treatments.		3 treatments.		4 treatments.		5 treatments.		6 treatments.		7 treatments.		8 treatments.		9 treatments.		10 treatments.	
	Cu-retted.	Not cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted	Not cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted.	Not Cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted.	Not cu-retted.	Cu-retted.	Not cu-retted.
No. cases	125	83	101	72	30	9	4	11	5	5	4	3	1	1	4	..	1	1	..	1
	43%	42%	34%	36%	10%	3%	1%	4%	1%	1%	.7%	.5%	.3%	...	.7%	..	...	.5%	..	.5%
Cures	117	79	96	67	29	7	3	9	4	2	2	1	1	...	2	..	...	1	..	1
	9%	7%	10%	10%	12%	100%	...	100%	66⅔%	100%	50%									
Relapses	1	5	10	5	3	4	...	3	2	2	1									
	3%	2%	1%	3%	.3%	1%	.3%	1%	.3%	1	.7%	1%	...	.5%	.7%	..	.3%			
Failures	8	4	5	5	1	2	1	2	1	3	2	2	...	1	2	..	1			
Cures not	10%	15%	3%	31%	13%	56%	66⅔%		66⅔%	25%										
followed	12	12	3	20	4	3	2	6												

The percentage of relapses, as in the other tables, to be of true statistical value, have been obtained after subtracting the "cured" cases that failed to remain under observation from the total of "cured" cases. The other percentages are obtained from the totals in the first vertical column. It will be seen that there is not much difference in percentage between the "cures" that followed curettage and those that were not curetted. Also the number of "cures" as a result of one treatment is about the same in both instances (Table XVI). As a matter of fact, however, there was quite a marked difference in this respect as in most of the curetted cases the second treatment was simply given as a precaution against recurrence. Whether or not this second treatment was necessary is not known. Table XVI gives at a glance the number of treatments required in the curetted and non-curetted cases. It will be noted that the percentage of recurrences is less in the curetted cases.

The percentages in Table XVI were obtained exactly as in Table XIV. Here we see that 43 per cent. of the total number of curetted cases was cured in one treatment and 42 per cent. of the cases that were not curetted was also cured in one treatment.

Effect of Location.—On account of the frequent statements to the effect that epitheliomata in certain locations are particularly recalcitrant it was thought advisable to classify the results according to locations. Table XVII provides these statistics.

TABLE XVII.—RESULTS ARRANGED ACCORDING TO LOCATION.

	Number of cases.	Cures.	Cured, not followed.	Relapses	Failures
		88%	12 %	11 %	11%
Nose	169	150	18	15	19
		99%	11 %	12 %	5%
Inner canthus	19	18	2	2	1
		100%	100 %		
External canthus	9	9	9		
		90%	60 %	27 %	9%
Forehead	61	55	33	6	6
		75%	100 %		25%
Eyebrow	4	3	3		1
		93%	50 %	14 %	6%
Cheek	90	84	42	6	6
		100%	43 %	33⅓%	
Lip	16	16	7	3	
		92%	100 %		7%
Chin	13	12	12		1
		78%	63 %	25 %	21%
Ear	14	11	7	1	3
		100%	70 %		
Behind ear	10	10	7		
		90%	60 %		9%
Eyelid	11	10	6		1
		91%	72 %	66⅔%	8%
Neck	12	11	8	2	1
		100%	19 %	4 %	
Trunk	26	26	5		
		85%	66⅔%		14%
Hand	7	6	4		1

According to Table XVII the most stubborn lesions are those located on the eyebrows. Here we find 75 per cent. cures and 25 per cent. failures as against 100 per cent. cures for lesions of the trunk, lip and the external canthus. The following is the key to Table XVII:

Refer to the nose cases (first transverse column). The total number of cases is 169. This includes the cures, 150 and the failures, 19. The unknown cases (patients not reporting after the cessation of treatment) are not included. The percentages of cures and failures are taken from the total 169. The percentage of relapses is obtained from the cures after deducting the "cured and not followed" cases.

Cases Grouped According to Clinical Type.—A compilation of statistics based on the clinical characteristics of the lesions offers material of prognostic value. In Table XVIII an attempt has been made to divide the cases into groups possessing distinct clinical characteristics. The nodular lesions were those which consisted of a single nodule, or a group of coalesced nodules. These lesions, while at times quite thick, were for the most part superficial. They ranged in size from a split-pea to a dime and, occasionally, a quarter. They were not ulcerated nor crusted. The ulcero-nodular lesions were nodular lesions which had undergone more or less ulceration. Many of these lesions were as large as a fifty-cent-piece and some were the size of a silver dollar. The superficial ulcers were lesions ranging in size from a split-pea to a silver dollar,

FIG. 218.—Rodent ulcer.

free of nodules and induration. At times these consisted of hardly more than a superficial erosion covered with a crust. The deep, indurated ulcers in size ranged from a silver quarter to an adult hand. The induration was dense and the ulceration extended into the subcutaneous tissue and in many instances involved the muscles and other important structures. The infiltrated plaques represent split-pea to quarter-sized areas of adherent hyperkeratosis with underlying infiltration. The verrucous lesion is the infiltrated plaque just mentioned with a papillomatous or verrucous surface.

FIG. 219.—Same as Fig. 218, after one ultraintensive *x*-ray treatment. This patient had previously received 100 or more fractional treatments. Subsequently there was a recurrence which failed to yield either to *x*-rays or radium.

The key to Table XVIII is as follows:

In the first horizontal column is shown the result obtained in the nodular type of epithelioma of which there were 171 cases which were kept under observation for at least a few months. The percentage of cures and failures is obtained from this total. The percentage of relapses is obtained from the cures after deducting the "cured and not followed" cases.

TABLE XVIII. RESULTS ARRANGED ACCORDING TO CLINICAL TYPE.

	Number of cases.	Cures.	Cured, not followed.	Relapses.	Failures.
		97%	15%	9%	2%
Nodular	171	166	25	13	5
		100%	13%	10%	
Superficial ulcer	65	65	9	6	
		88%	13%	8%	11%
Ulcero-nodular	111	98	13	7	13
		66%	21%	31%	33%
Deep infiltrated ulcer	56	37	8	9	19
		95%	9%	....	4%
Infiltrated plaque	23	22	2	....	1
		9%	....	....	9%
Verrucous	11	10	....	....	1
		95%	26%	5%	4%
[illegible]	24	23	6	1	1

It will be seen that the highest percentage of cures and the smallest percentage of recurrences were obtained in the superficial ulcers. Next in order come the ulcero-nodular, and the infiltrated plaque.

Table XIX shows the number of treatments administered to the various clinical types. Only the "cured" cases and the failures are recorded. It will be noted that 91 per cent. of the infiltrated plaques responded to one treatment as against 81 per cent. for the verrucous, 60 per cent. for the superficial ulcers, and 48 per cent. for the nodular lesions.

TABLE XIX. LESIONS OF VARIOUS CLINICAL TYPES ARRANGED ACCORDING TO NUMBER OF TREATMENTS.

Clinical appearance	No. cases	1	2	3	4	5	4	7	8	9	10
		48%	34%	8%	4%	1%	.5%				
Nodular	167	81	59	15	8	3	1				
Superficial		60%	33%	4%	.	.	1%				
ulcer	65	39	22	3	.	.	1				
Ulcero-		34%	44%	9%	3%	4%	2%				
nodular	105	36	47	10	4	5	3				
Deep		[illegible]	51%	20%	5%	2%					
infiltrated	54	10	28	11	3	2					
ulcer											
Infiltrated		90%	8%								
plaque	23	21	2								
		81%	18%								
Verrucous	11	9	2								
[illegible]		[illegible]	[illegible]		.	.	5%	5%	11%	5%	2%
	[illegible]	[illegible]	13		.	.	2	2	4	2	1

Degrees of Reaction Observed.—Table XX shows the effect of varying degrees [illegible] the epitheliomata. Omitting the third degree reactions [illegible] showing no reaction, on account of their small numbers, we find [illegible] percentage of cures and the smallest percentage of failures [illegible] in connection with reactions of the second degree.

[illegible] Age on Results. Table XXI records the results in individuals of [illegible] these statistics indicate that the best results are obtained in [illegible] and sixty years of age but the number of cases was too

TABLE XX.—RESULTS IN RELATION TO DEGREE OF REACTION.

Reaction.	Number of cases.	Cured.	Cured, not followed.	Relapses.	Failures.
No reaction	29	99% 27	3% 1	....	6% 2
1st degree	49	87% 43	4% 2	9% 4	13% 6
2d degree	19	87% 17	... ...	35% 6	10% 2
3d degree					

small to be of value. The next best showing was between the ages of seventy-one and eighty-five, although when the table is carefully studied it is seen that age makes very little difference. The percentages were estimated in the same manner as those in Table XX.

TABLE XXI.—RESULTS IN RELATION TO AGE OF PATIENT.

Age.	Number of cases.	Cures.	Cures, not followed.	Relapses.	Failures.
20–30	12	91% 11	27% 3	25% 2	8% 1
31–40	48	89% 43	37% 16	14% 4	10% 5
41–50	106	85% 91	18% 17	16% 12	14% 15
51–60	121	97% 118	10% 12	10% 11	2% 3
61–70	77	89% 69	20% 14	3% 2	10% 8
71–85	40	95% 38	2% 1	5% 2	5% 2
Unknown	57	89% 51	....	5% 3	10% 6

Effect of Sex on Results.—The last table (Table XXII) shows the results in relation to sex. The best results were obtained in females. The percentages here were obtained in the same manner as those of the preceding table.

TAPLE XXII.—RESULTS IN RELATION TO SEX.

Sex.	Number of cases.	Cures.	Cures, not followed.	Relapses.	Failures.
Male	232	90% 210	15% 33	10% 18	9% 22
Female	229	92% 211	14% 30	9% 18	7% 18

Statistics Found in the Literature.—While there is a voluminous literature dealing with the *x*-ray treatment of cutaneous basal-cell epitheliomata, there are very few articles that give carefully compiled statistics. Pusey's statistics, published in 1907, do not differentiate between the basal-cell and the prickle-cell types. In reading this article one gains the impression that most of the cases were of the basal-cell variety. The report was b
were observed from three to six years. Four of the
cured but relapsed.

original percentage of 90 is not materially reduced. It will be recalled that the cases that were observed for five years showed a percentage of permanent cures of 94; four year cases, 80 per cent.; three year cases, 82 per cent.; two year cases, 85 per cent. These percentages can be increased by omitting the recurrences that again healed under the influence of the roentgen-rays.

FIG. 220.—Rodent ulcer.

FIG. 221.—Same as Fig. 220, after two hyperintensive x-ray treatments. No recurrence in eight years.

FIG. 222.—Rodent ulcer with indurated margin which had failed to heal under the influence of long-continued fractional roentgenization.

FIG. 223.—Same as Fig. 222, after four hyperintensive, filtered x-ray treatments. A subsequent recurrence failed to be influenced by x-rays or radium.

Comparison of Methods of Treatment.—Now let us see how these statistics compare with those associated with other methods of treatment. Hazen reports a series of 178 basal-cell epitheliomata which

were treated by surgical excision. Twenty-eight patients were his own, the remainder being borrowed from the service of Dr. Bloodgood at Johns Hopkins Hospital.

Sixty-four patients were kept under observation for more than three years. Four of these patients were well at the end of three years; 13 at the end of four years; 39 after five or more years. In 7 instances there was a recurrence. This gives a percentage of permanent cures of 86 in the unselected cases. There were 5 practically hopeless cases and if these are omitted and only the selected cases considered, the percentage of cures will amount to 93. A further study of the treated cases, as regards the duration and the extent of the lesion, gives the following data:

Duration.	Cured.	Recurrent.
1 year	17	2
2 years	8	
3 years	9	
5 years	12	3
10 years	17	3

Size.	Cured.	Recurrent.
Under 1 inch	33	2
1 to 2 inches	19	2
Extensive	4	4

It will be seen that there is really very little difference, according to statistics, between the results obtained by surgical excision and by *x*-ray treatment. Sherwell obtained 90 per cent. of permanent cures in unselected cases with the vigorous use of acid nitrate of mercury after a thorough curettage, but this estimation is not based on carefully compiled statistics. The literature does not appear to contain statistics based on the use of the various caustics such as arsenic, carbon dioxid snow, zinc, actual cautery, desiccation, etc. It has been claimed by A. Robinson and others that arsenical paste, if properly employed, gives as high a percentage of permanent cures as does any other method. It is the consensus of opinion among dermatologists that a vigorous-acting caustic if thoroughly applied constitutes an excellent method of treatment. On the other hand, there seems to be very little confidence in carbon dioxid snow, superficial caustics, electrolysis, and similar agents.

Method of Election.—The object of any treatment is to destroy every malignant cell. If this can be accomplished a cure is the result. So far as concerns statistics this object in unselected cases is most nearly attained by irradiation or by excision.

Both methods possess advantages and disadvantages. The principle disadvantage of excision is the difficulty of removing all pathological tissue. This is especially true in large, deep-seated, adherent lesions or lesions that are situated in inaccessible locations such, for instance, as the inner canthus. Even when dealing with a small epi
limited entirely to the skin and situated in a favorable loca
surgeon, in an endeavor to obtain a good cosmetic result and

reasons, is likely to cut too close to the macroscopical lesion ther leaving malignant cells *in situ*. In a number of supposedly succes

FIG. 224.—A superficial basal-cell epithelioma near the breast and a deep rodent u in the axilla.

FIG. 225.—Same as Fig. 224, after one hyperintensive, unfiltered x-ray treatment appl to each lesion. No recurrence in seven years.

excisions the author has obtained the excised tissue *in toto*, cut it serially and found that the proliferated epithelial cells extended to the edge of the incision. It is a question if such an examination should not be made after every excision and if the indications warrant, x-rays or radium can be employed to prevent a recurrence.

Other objections to excision are the shock to old and feeble persons, loss of time, pain and deformity.

When treating epithelioma, even a small basal-cell growth, the principle object is to completely destroy the disease. While the cosmetic result is worthy of serious consideration, it is of secondary importance. It is the duty of the physician to select a method of treatment that in his opinion will most likely eradicate the disease. If there is a method that will accomplish this purpose and at the same time give a superior cosmetic result, such treatment will constitute the method of election.

FIG. 226.—Ulcero-nodular basal-cell epithelioma of the nose.

FIG. 227.—Same as Fig. 226, after one ultraintensive x-ray treatment. No recurrence in seven years.

Small lesions can be destroyed with x-rays or radium and the cosmetic result is so perfect that it is impossible to detect the former site of the disease. On the other hand there is always the possibility of such sequelæ as atrophy and telangiectasia. In this connection, in the author's series of 644 patients, there were only 6 cases of telangiectasia and these occurred in recalcitrant cases that required considerable treatment. Telangiectasia subsequent to a first or second degree radiodermatitis is not an uncommon phenomenon and it is curious why it does not occur more often in epithelioma cases. Possibly this "immunity" is due to the fact that most of the patients are beyond forty years of age.

Excision always leaves more or less scarring. Ulcerated lesions that involve the true skin or the subcutaneous tissue will leave a scar no matter how treated, but the deformity is less subsequent to irradiation than with any other form of treatment. Without entering into further

argument suffice it to say that insofar as concerns cosmetic results x-rays and radium offer distinct advantages over other methods.

It is doubtful if there can be a method of election for unselected cases of basal-cell epithelioma. The experienced physician will select the

FIG. 228.—A deep-seated, indurated, basal-cell epithelioma. Photograph was taken a few days after first treatment; note the areola of x-ray erythema.

FIG. 229.—Same as Fig. 228, after two hyperintensive x-ray treatments. The patient died (pneumonia) three years after the last treatment. There was no recurrence.

treatment that promises the best result in the individual case. However, assuming that excision, powerful caustics combined with curettage, or irradiation will, when adequately applied, cure the average case of basal-cell epithelioma, the author favors the last method. The reasons for the selection are as follows: There is no pain nor inconvenience in the case of a healthy and active person and no shock, mental or physical, to aged or weak or nervous patients. There is no interference with vocations. The often injurious psychological effect of surgery is avoided. The cosmetic results are superior to those obtained by other methods. It is, therefore, a good routine in practically all cases to try irradiation first.

Prognosis Affected by Previous Treatment.—It is well known that certain methods of treatment or almost any treatment inadequately applied, may make a basal-cell epithelioma more recalcitrant. Presumably this increased malignancy is caused by the stimulating action of such treatment on the malignant cell together with a lowering of vitality of the surrounding tissues. Table II shows that the most stubborn lesions are those that have received repeated courses of *x*-ray treatment administered in small doses. It is advisable, therefore, when selecting a method of procedure, to consider the previous treatment and its result. If there is a history of long-continued irradiation, or if the skin in the neighborhood of the lesion (original or recurrence) shows roentgen-ray sequelæ, it would seem advisable to employ some method other than *x*-rays or radium.

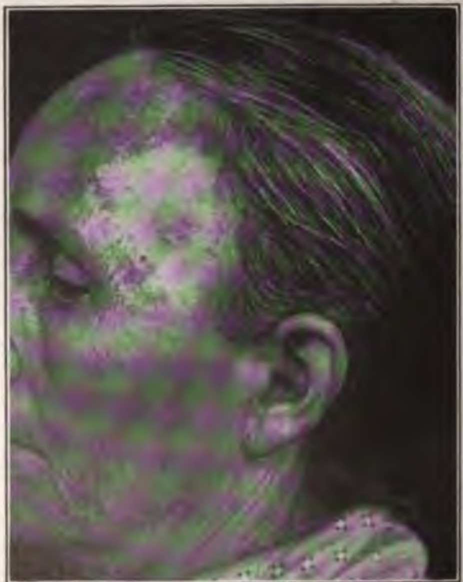
Recalcitrant Lesions.—If a lesion does not respond at once to hyperintensive radiation it is advisable to utilize some other method instead of proceeding with roentgenization indefinitely. Some roentgenologists will not agree with this statement. They are convinced that every basal-cell epithelioma can be cured with the *x*-rays or with radium if the dose is sufficiently intensive, the treatment being pushed to the point of producing a third degree radiodermatitis if necessary. In confutation of this opinion the author has studied tissue removed from *x*-ray ulcers (on the site of a basal-cell epithelioma) of long duration and found actively proliferating epithelial cells deep in the tissue or at the edge of the ulcer.

When *x*-rays or radium fail to cure a basal-cell epithelioma, the failure is nearly always due to neglect, poor judgment, inadequate or improper treatment, etc. However, it must be admitted that there are basal-cell tumors, even very small lesions that have never been treated, that simply cannot be cured with these agents. Fortunately such instances are rare.

If irradiation is going to be successful there will be a distinct improvement subsequent to the first intensive or hyperintensive treatment. If such improvement is not manifest, further irradiation is contraindicated. It occasionally happens that a lesion will show improvement after the first two or three treatments and then irradiation loses its efficacy. In such instances additional irradiation is not warranted.

Versus Fractional Treatment. It is generally agreed that eatment is contra-indicated in the treatment of epithelioma.

.—Large ulcero-nodular basal-cell (?) epithelioma before treatment. (Courtesy of Dr. W. A. Pusey.)



Same as Fig. 230. This patient was treated in 1903. No recurrence. (Courtesy of Dr. W. A. Pusey.)

In former years it was the practice to administer small doses once or twice weekly until an erythema developed or until the lesion disappeared. It was not unusual to give fifty or even a hundred such treatments. The percentage of clinical cures was small and the percentage of recurrences was large. There is reason to believe that small doses stimulate the malignant cell and unless these small amounts are administered with sufficient frequency to provide rapid accumulation the result is likely to be undesirable. Under fractional treatment the disease may disappear, but it is more likely to persist and even progress more rapidly and it may become more recalcitrant to any form of treatment. As a rule an epithelioma that has been treated with fractional irradiation will not respond favorably to an intensive treatment unless several months have elapsed since the last fractional treatment was administered. Pusey has always been an advocate of fractional treatment and his results have been excellent. The explanation is simple. Pusey's fractional treatment does not correspond with fractional treatment as outlined in Chapter XIX. His dose is much larger and the intervals between treatments are shorter. The desired effect is obtained within a month so that his routine is intensive rather than fractional. As outlined in Chapter XIX intensive treatment may consist of a single erythema dose or smaller doses so spaced in time that the effect is the same.

Preliminary Curettage.—Fordyce was the first to suggest preliminary curettage. Belot and others have found the idea an excellent one. The method has advantages and disadvantages. The procedure is surgical and is associated with many of the objections given when discussing surgical methods. While it is decidedly advantageous to precede irradiation by curettage this step is by no means necessary in the majority of cases. With preliminary curettage one is more certain to obtain a cure in one or two treatments, especially is this true of nodular, or deep-seated, or indurated lesions. In well-advanced lesions the percentage of clinical cures is greater with than without curettage. Basal-cell epitheliomata being non-metastatic, curettage may be performed with safety.

Quality of Radiation.—There is a difference of opinion among roentgenologists as to the best spark-gap length to use for the treatment of cutaneous epithelioma. Some writers advise a 9-inch spark gap and heavy filtration for all cases; others prefer a shorter spark gap (3 to 6 inches) without filtration. Schultz has obtained good results with a 2-inch spark-gap in cases that failed to yield to a more penetrating radiation. At times a lesion that failed to involute under the influence of unfiltered radiation will disappear when subjected to filtered radiation. The opposite also occasionally happens. Unfortunately there is no statistical evidence pointing to the superiority of any given wave length used as a routine. The author's impression is that it makes little difference what spark-gap is used, within reasonable limits, as a routine. But it is inadvisable to establish a routine technic. If all

visible or palpable evidence of disease is removed with a curette it is difficult to understand the advantage of applying filtered radiation to the open wound. Theoretically, "soft" radiation would be of possible advantage here. Small, very superficial lesions seem to respond equally well to filtered or unfiltered radiation. Filtration is specifically indicated in large, thick lesions, especially when the entire derma and the subcutaneous tissue are involved.

Dosage.—Hyperintensive treatment is advised. The dose is repeated in four weeks providing the reaction subsequent to the first treatment has subsided. In some instances it may be necessary to wait six or eight weeks before administering the second treatment. Hyperintensive treatments are continued until the disease is clinically cured. If four to six such treatments fail to effect a clinical cure it is preferable to institute some other form of treatment. The exact size of the dose will depend upon the age of the patient, the size, thickness, depth and location of the lesion, etc. It will range from H1 to H2 S. D., unfiltered (see Chapter XIX).

Eyelid Lesions.—The main question here concerns suitable protection of the eye. While this organ tolerates large amounts of radiation without injury, it should be protected as much as possible. If the lesion is situated on the lower lid, the lid can be pulled away from the eyeball and fastened in place by a strip of zinc plaster, one end of which is attached to the lid while the other end is fastened to the neck. When treating lesions on the upper eyelid it is customary to cocainize the eye and to insert under the lid several layers of gauze which have been thoroughly impregnated with a thick zinc oxide paste. Lead foil may be used instead of the gauze.

For advice relative to the treatment of convex and concave surfaces, protection of healthy tissue, cross-fire and general technical details, see Chapter XIX.

Causes of Failure.—*Failure to Destroy Lower Strata of Cells.*—A lesion may appear to be clinically cured while the epithelial cells in the deeper part of the growth continue to proliferate. Or such cells may remain inactive for a few weeks or months and then begin to proliferate. It is even possible that the lowermost cells in a large tumor may show increased activity during the course of treatment. Failure to apply a lethal dose to these cells may be due to the use of unfiltered radiation when filtration is indicated, or the individual or collective dose may be too small. In order to apply a lethal dose to deep-seated cells it is often necessary to use filtered radiation, to cross-fire and to apply as large doses as possible without seriously injuring normal tissue.

Resistant Cells.—Rarely one encounters an untreated basal-cell epithelioma that fails to involute under the influence of *x*-rays or radium. Such resistance is common in cases that have been inadequately or improperly treated with these or with other therapeutic agents. In either instance it is inadvisable to continue the use of *x*-rays or radium beyond a fair trial.

It is probable that cells comprising a malignant neoplasm vary in susceptibility to irradiation and this variation is due to the life cycle of the cell. A cell during its rest stage is less susceptible than one that is undergoing division. It is conceivable, therefore, that at the moment of treatment, there might be cells capable of resisting the usual therapeutic dose (see Chapter XVIII). This theoretical possibility suggests the advisability of one or two "prophylactic" treatments when a lesion is apparently cured with one application. The prophylactic doses may be intensive or subintensive, rather than hyperintensive.

Theoretically there is a better way to insure against the escape of cells in the rest stage. Kingery has shown that 50 per cent. of *x*-ray effect is lost in three and a half days; therefore to keep the tissue in a state of saturation for a period of several weeks it is necessary to administer one-half saturation dose every three and a half days. The details of Kingery's method are given in Chapter XVIII.

Inadequate Dosage.—No one has estimated, experimentally, the amount of radiation required to destroy all the malignant cells in a basal-cell neoplasm. Wood and Prime, and others have determined the lethal dose for metastatic epithelioma (Chapter XVIII). Practical experience shows that the lethal dose for basal-cell epithelioma is considerably less than for metastatic epithelioma. A single erythema dose, properly administered, will suffice for many tumors of the basal-cell type. Judgment, experience and skill in observation are required to determine adequate treatment in a given case. It is preferable to apply a little more radiation than is necessary rather than an amount that is inadequate, but this must not be carried to the point of undue injury to normal tissue. It is not justifiable to effect a third-degree radiodermatitis nor to cause an injurious degree of atrophy or sclerosis.

Failure to Destroy Peripheral Cells.—Most recurrences begin at the edge or just beyond the periphery of the former lesion. This may be due to too close shielding. Histological studies and practical experience demonstrate that malignant cells may extend for several millimeters or even centimeters beyond the visible or palpable edge of the lesion. It is essential, therefore, that at least one-quarter inch, preferably one-half inch, of normal skin around the lesion be included in the field of radiation.

Convex lesions, very large lesions, and lesions situated in inaccessible locations may interfere with the application of the lethal dose. Information relative to treatment under such conditions will be found in Chapter XIX.

Inadequate Observation.—After a clinical cure has been established the site of the former lesion should be inspected every six months for five years. Failure to keep patients under observation has been the cause of many obstinate and destructive recurrences. The observer should be able to detect the earliest evidence of recurrence in, under, or beyond the scar.

Radium.—It is the opinion of the writer that as a routine treatment for basal-cell epithelioma x-rays and radium have the same value. In individual cases, however, there is a difference. Occasionally a tumor will involute under the influence of radium beta rays after x-rays have failed to be of benefit. The author has never been able to cure a basal-cell epithelioma with x-rays after failing with radium. Also he has not been able to accomplish with gamma rays what could not be done with x-rays. Radium is more convenient and, for this reason, more efficacious, when the disease is located in inaccessible locations, such as the edge of the eyelid, the external auditory meatus, or when the nasal or buccal mucosa is involved. Also, in many instances, it is easier to cross-fire, or to obtain a plane radiating surface for convex and irregular surfaces, with radium than with x-rays. At times both agents may be used to advantage as, for instance, a tumor on the nose might be treated by applying x-rays externally while a radium tubular applicator is placed in the nose.

The writer has a distinct impression which, however, is not supported by statistics, that beta rays are more efficacious than are gamma rays. Therefore when possible it is preferable to utilize beta rays. Judgment is required in selecting cases for beta ray therapy. If a tumor is more than 2 cm. in depth it is preferable not to use beta rays unless the location or the shape of the tumor is such as to permit cross-fire treatment. Unfiltered applicators are contra-indicated. A screen of from $\frac{1}{10}$ to 3 mm. of aluminium or the filtering equivalent in some other material should be used, the degree of filtration depending upon the thickness of the tumor. It is permissible to employ radium needles in the treatment of basal-cell epithelioma because there is no danger of metastasis. For further information relative to radium technic and the relative value of radium and x-rays, see Chapters XII and XIX.

PRIMARY PRICKLE-CELL EPITHELIOMA.

Cutaneous epithelioma of the squamous or prickle-cell type may develop in the skin or in the mucosa. The writer agrees with Pusey, Boggs and others who aver that most of these growths can be eradicated with x-rays or radium if the lesion is recognized sufficiently early and the treatment is immediately and properly applied. But he is not in accord with men who advise irradiation as the method of election in cases of well-developed prickle-cell epithelioma even when there are no palpable glands.

Prickle-cell epithelioma is an exceedingly dangerous affection. Success lies in early diagnosis and the immediate institution of radical treatment. Delay in diagnosis, or delay in instituting treatment, or inadequate treatment, is hazardous because metastasis may occur at any moment. The absence of palpable glands does not mean absence of metastasis. Very frequently local growths are permanently cured only to have the disease appear in the neighboring lymphatics a few months or a year or two later. This happens after surgery and after

FIG. 232.—Keratosis involving the entire lower lip. No perceptible underlying infiltration. Probably precancerous.

FIG. 233.—Same as Fig. 232, after two hyperintensive *x*-ray treatments. The horny layer was first removed. There was a little leukoplakia which also disappeared. No recurrence in seven years.

FIG. 234.—An ulcerated *x*-ray keratosis occurring on the hand of a pioneer *x*-ray technician, probably a beginning prickle-cell epithelioma.

FIG. 235.—Same as Fig. 234, after two radium treatments (beta rays). No recurrence in three years.

irradiation in cases that do not exhibit evidence of metastasis at the time of treatment. It is probable, in such instances, and even in very early cases, that metastasis occurred prior to the treatment.

Because of the possibility of malignant cells being present in the neighboring lymphatics it is customary to irradiate the lymphatics that drain the site of the lesion. While there is no convincing statistical evidence that such treatment is of value, the method is indicated theoretically. Furthermore it is the opinion and impression of surgeons, radiologists and dermatologists that such treatment is of great value. As there is substantial clinical evidence for this opinion every patient with prickle-cell epithelioma, whether the primary growth is irradiated or excised, should receive the possible or probable benefit to be derived from such treatment. Incidentally many surgeons after excising a lesion, not only advise irradiation of the neighboring lymphatics but also the site of the former lesion.

FIG. 236.—Prickle-cell epithelioma.

FIG. 237.—The same as Fig. 236, after two hyperintensive doses of filtered x-rays. No recurrence for five years.

Transitional lesions, that is, a lesion in the transitional stage between a preëpitheliomatous growth and a true epithelioma and, also, very small prickle-cell epitheliomata of the skin or mucosa, can be destroyed with x-rays or radium with a reasonable degree of certainty. After the lesion has become indurated, ulcerated, and has invaded the deeper derma and perhaps the subcutaneous tissue, the result of irradiation is uncertain. We recall with pardonable pride and pleasure our suc-

cessful cases, and endeavor to forget the poor unfortunates who failed to respond favorably to the treatment. Success in the writer's hands has been limited to a very small percentage of unselected cases.

It is a well-known fact that the degree of malignancy is not always the same in tumors of the same morphological type; also that the tumors behave differently when irradiated. The writer has failed to cure small, but rapidly growing tumors having a duration of from three weeks to three months; failures have occurred, also, in less malignant tumors. On the other hand inoperable and apparently hopeless cases have been clinically cured and have remained well for from two to seven years.

Statistics.—*X-ray.*—**Bisserié** reports 24 cases of epithelioma of the lip with 14 cures, 8 failures and 2 recurrences. Also 17 cases of epithelioma of the tongue with 2 cures, 14 failures and 1 recurrence. The period of observation was fifteen months.

Boggs claims 90 per cent. of cures in early epithelioma of the lip and above 50 per cent. for advanced cases. He does not give tabulated statistical results.[1]

Radium.—**Greenough** reports on the radium treatment of inoperable cases with palpable glands as follows:

	Number of cases.	Clinical cures.
Lip	19	4
Mouth	5.3	0

Sweitzer obtained 36 clinical cures out of 43 cases of epithelioma of the skin and of the lip. The cases included both basal-cell and squamous cell growths.

Duane and Greenough report as follows:

		Number of cases.	Clinical cures.
Lip		19	4
Mouth		62	1
Skin	Carcinoma	83	33
	Epidermoid cancer	58	15
	Rodent ulcer	34	12
	"Epithelioma"	21	9

Janeway's statistics are:

	Number of cases.	Clinical cures.
Lip	24	6
Tongue	50	4
Skin (mixed types)	93	66

Burrow's statistics:

	Number of cases.	Well at end of 1 year.
Lip	12	2
Skin (squamous)	51	9
Mouth and tongue	154	10
Rodent ulcer	123	62

Statistics reported by Pinch

	Number of cases.	Clinical cures.
Skin (squamous)	74	10
Mouth	311	6
Rodent ulcer	508	322

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[1] Hazen reports on the x-ray treatment of prickle-cell epithelioma as follows: Number of cases, 15; clinical cures, 7; permanent cures, 4.

Surgery.—Broders reports on 537 cases of squamous-cell epithelioma of the lip. Of the patients operated and traced, 40.52 per cent. are dead; 59.48 per cent. are alive. Of the latter 92.85 per cent. have been free of epithelioma for an average of 7.76 years. Of the patients who died at various lengths of time after a clinical cure and about whom information has been received, 63.63 per cent. died from epithelioma. The operative mortality was only 0.77 per cent. The lymph nodes were removed in 87 per cent. of the cases. Of these, 23 per cent. showed evidence of metastasis. Of the total of 537 patients 78.14 per cent. are now free of epithelioma or have died from diseases other than cancer.

Murphy, quoted by Boggs, admits 52 per cent. failures in favorable cases and a mortality of 75 per cent. in patients who have palpable glands.

Bloodgood finds that post-operative mortality has been reduced in recent years by new methods of surgery and early diagnosis. In the last five years he has operated on 14 cases of epithelioma of the lip in which there have been but two recurrences.

Butlin reports on 197 cases of epithelioma of the tongue as follows:

Died from effect of operation	20
Failed to remain under observation	1
Died of recurrence	91
Palliative operations	8

Twenty-two patients are either free of recurrence at the end of three years or have died from some disease other than epithelioma. Fifty-five patients are alive and well. The period of observation ranges from three to twenty-one years.

Combined Treatment.—There is a large number of articles dealing with surgical methods combined with irradiation but while the results reported are very encouraging, few of these articles give statistics. Pfahler, Clark, Lain, Peters and many others have written on this subject.

Comments.- The figures quoted in most of the statistical reports are not such as to cause elation, especially when one does not know the details of the cases. Many of the reports, especially those dealing with radium, relate mostly to inoperable, almost hopeless cases. The high percentages of cures obtained by some authors are due largely to the fact that the cases were favorable ones.

The successful results obtained in early or favorable cases with radical treatment demands that attention be focused on early diagnosis and the institution of immediate and radical treatment. At the present writing the author regards well-developed, prickle-cell epithelioma of the skin or the mucosa, a surgical disease and it should receive radical surgical treatment. There is reason to believe that preliminary and especially post-operative irradiation at the site of the lesion and also irradiation of the lymphatics that drain the region of the lesion, is of great service in completely eradicating the disease.

For information relative to the lethal dose for cancer cells and the "radiosensitiveness" of different types of cancer cells, the reader is referred to Chapter XVIII.

The occasional excellent results obtained in inoperable cases with radium and *x*-rays warrants the use of these agents in all such cases.

The results obtained in apparently hopeless cases with a combination of fulguration (desiccation) *x*-rays and radium, by Pfahler, Clarke and others, should make one refuse to consider a case as positively incurable until this method has been given a trial.

Technic.—The technic of application does not materially differ from that described under the heading of basal-cell epithelioma. Here, the desire for a good cosmetic result must not interfere with adequate treatment. The dose must be large, sufficient to effect a first-degree reaction. Advantage should be taken of the cross-fire method whenever possible. It is essential not to stimulate the malignant cells in the deeper part of the lesion. To avoid this it is advisable to use heavily filtered gamma rays or filtered *x*-rays if the lesion is more than a centimeter or two in thickness. Lesions that are less than 2 cm. in thickness may be treated with filtered beta rays. The treatments are given at intervals of three or four weeks or the tissue is kept

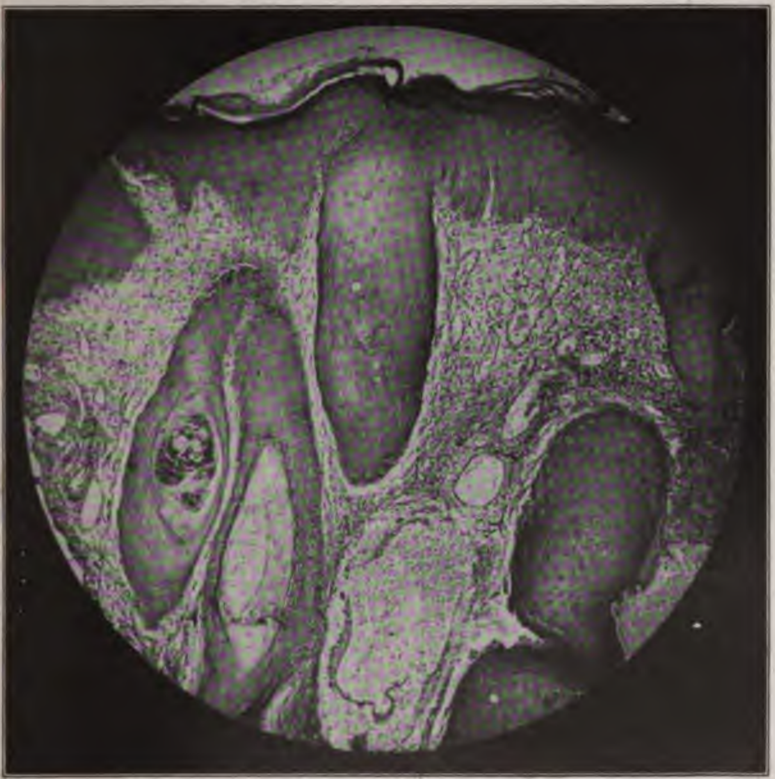

FIG. 238.—A section of tissue obtained by a biopsy from patient shown in Fig. 236. Section shows a prickle-cell epithelioma.

under the influence of the radiation for two or three weeks by the method advocated by Kingery (see Chapter XVIII). If there is no improvement subsequent to the first treatment, or if at any time the lesion ceases to improve, it is advisable at once to institute some other form of treatment.

FIG. 239.—Keratosis of the mucous membrane of the lip with underlying infiltration; an early prickle-cell epithelioma.

FIG. 240.—Same as Fig. 239, after two hyperintensive x-ray treatments.

FIG. 241.—A well-developed prickle-cell epithelioma of the lip, without palpable glands in the neck. Photograph taken in 1903. (Courtesy of Dr. W. A. Pusey.)

FIG. 242.—Same patient as shown in Fig. 241 after x-ray treatment. This photograph was taken in 1912. (Courtesy of Dr. W. A. Pusey.)

In all cases the neighboring lymphatics should be irradiated to the point of skin toleration with heavily filtered radiation. In case of

palpable glands such treatment is continued until the glands subside or until the patient is beyond hope. In the absence of palpable glands it is difficult to say how much treatment should be given. It is usual to administer from three to six, filtered, cross-fire treatments at monthly intervals.

It is the concensus of opinion that it is dangerous to curette prickle-cell growths on account of the possibility of metastasis. The same is probably true relative to the insertion of radium needles. For further technical details see Basal-cell Epithelioma, also chapters on Radium Technic, Filtered and Unfiltered *X*-ray Technic, General Therapeutic Considerations, and Effect of *X*-rays and Radium on Pathological Tissue.

SECONDARY EPITHELIOMA OF THE SKIN.

Secondary cutaneous epithelioma may be the result of metastasis from a primary visceral lesion, a lesion of the breast, or a primary skin tumor. Such cutaneous epitheliomata occur as multiple, fairly deep-seated, firm, nodules. These lesions are much more susceptible to irradiation than are the parent lesions. They should be treated with the intensive, filtered technic.

There is a type of secondary cutaneous epithelioma known as cancer en cuirasse, also lenticular carcinoma and carcinomatous lymphangitis. It is extremely recalcitrant. The writer has treated four advanced cases of this type without benefit. In two very early cases the process was temporarily arrested.

PAGET'S DISEASE.

Fordyce (1904) was the first to report the use of *x*-rays in Paget's disease. The lesion was in the gluteal region and the diagnosis was confirmed by biopsy. The lesion was cured by fractional treatment and there was no recurrence. Hartzell (1906) reported the clinical cure of two cases of Paget's disease of the breast. In one patient mammary carcinoma developed during treatment and in the other patient there was a suspicious nodule in the breast several months after the cutaneous lesion had disappeared. The technic was fractional. In the same year Bisserié reported the cure of 7 of 9 cases with intensive technic. Taylor (1907) cured a case of Paget's disease of the breast with fractional treatment but mammary carcinoma developed during the treatment. Jackson cured a case of extramammary Paget's disease—the lesion was on the cheek. Belot, Terzaghi and Campana, Sequeira and others, have reported the successful treatment of Paget's disease of the breast. Boggs states that he has cured a number of cases of Paget's disease of the breast. Several of the patients have remained well for ten years. The entire breast and axilla was included in the field of radiation. The writer can add 3 cases that were cured with from two to four subintensive, unfiltered treatments and 1 case that recovered under fractional treatment. There has been no recurrence

and no mammary carcinoma in periods of two, three and six years. In 1 case of Paget's disease of the cheek there was no improvement.

Technic.—In extramammary Paget's disease, unfiltered radiation may be employed and the method may be either fractional or intensive. Because epithelioma of the glandular tissue of the breast is such a common associate of Paget's disease of the breast, it seems advisable to apply filtered radiation to the entire breast and axilla in the same manner as the lymphatic glands are irradiated when treating primary prickle-cell epithelioma of the skin or mucosa. In any event the patient should be kept under observation.

SARCOMA.

Sarcomata are among the least common of cutaneous neoplasms and it is largely for this reason that so little practical knowledge relative to the action of *x*-rays and radium has been accumulated. The different types of sarcoma, of which there are many, vary considerably in malignancy. Fibrosarcoma is the least dangerous. Giant-cell sarcoma is relatively benign. Melanomata are exceedingly malignant as, also, is the subcutaneous round-cell sarcoma. Sarcomata also vary considerably in "radiosensitiveness." Abbe has found radium to be a specific in the giant-cell type and this agrees with the writer's experience (filtered beta rays). Fibrosarcoma and lymphosarcoma yield readily to both *x*-rays and radium (Pfahler, Janeway and others). Bisserié treated 8 cases of diffuse sarcoma with *x*-rays and obtained 100 per cent. of clinical cures. There were no recurrences for fifteen months. Belot cured 2 similar cases. The author has not been so

FIG. 243.—Kaposi sarcoma.

FIG. 244.—Same as Fig. 243, after several subintensive treatments.

fortunate. This type of sarcoma is usually a round-cell growth which begins in the subcutaneous tissue and involves the skin secondarily. It may be a primary growth or it may be the result of metastasis from a primary tumor in the skin or some other tissue. The type is malignant. Six cases have been treated with x-rays. In 4 instances there were subcutaneous nodules scattered over the body which occurred subsequent to excision of a single cutaneous tumor. The individual nodules disappeared as a result of one or two hyperintensive filtered doses, but new nodules continued to appear until the patient died or discontinued treatment. The same result was obtained in 1 patient who was treated with radium gamma rays. One patient, who exhibited three ulcerating tumors (round-cell type) made a complete recovery (x-rays) and there has been no recurrence for two years.

FIG. 245.—A rapidly growing sarcoma occurring in a patient who had lesions of sarcoma of the Kaposi type.

FIG. 246.—Same as Fig. 245, after one hyperintensive x-ray treatment.

Bisserié treated 12 cases of melanosarcoma with massive doses of x-rays. All were clinically cured, but there were 3 recurrences. The writer has cured 3 cases of primary melanosarcoma with x-rays without recurrence for two, five and eight years respectively. There was complete failure in two primary tumors. In 4 cases of multiple secondary tumors the individual tumors involuted under treatment, but the patients died from pulmonary sarcomatosis.

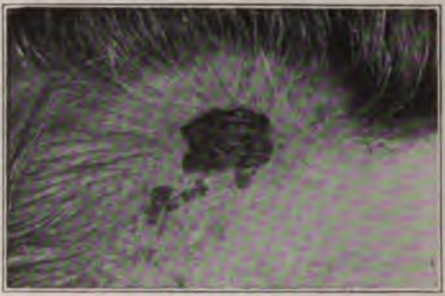

FIG. 247.—Melanoma. Note the outlying satellites. Patient referred by the late Dr. J. C. Johnston.

At times the result of x-ray or radium treatment of cutaneous sarcoma is spectacular; at times it is extremely disappointing. More experience will be required before the true value of these agents in the various types of sarcoma can be stated and compared with the results obtained by surgeons.

The technical details required for the treatment of sarcoma do not differ from those given for epithelioma.

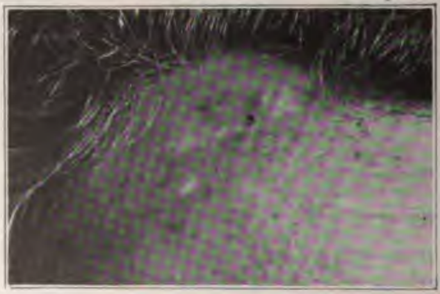

FIG. 248.—Same patient shown in Fig. 247, after several intensive x-ray treatments. There was a relapse in a few months. Two hyperintensive filtered treatments were then given. There has been no recurrence since November, 1914.

Kaposi's Sarcoma (*Sarcoma Idiopathicum Multiplex Hemorrhagicum*) —This cutaneous entity can be kept under control more or less indefinitely with x-rays or radium. It is even possible to permanently cure

some cases. Irradiation is the method of election although there is no harm in combining with other forms of treatment such, for instance, as the administration of arsenic. Under the influence of irradiation the individual plaques and tumors will disappear, but new lesions may continue to develop. Both fractional and intensive doses have been successful. Subintensive doses are to be preferred.

Hartzell, Williams, Halle, Lustgartene, Groigoryev, Bulkley, Gilchrist and Ketron, and many others, have reported good results with *x*-rays. The author has a series of 9 cases of which 7 were treated with unfiltered *x*-rays and 2 with filtered radium beta rays. The result was splendid in all of the patients. In all but 3 cases new lesions developed occasionally until the patients went to some other clinic. In 3 instances there have been no new lesions for over two years.

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Figs. 212 to 217, 220 to 227, 232, 233, 236, 237, 238, 247 and 248 were published in the Journal of the American Medical Association for November 27, 1915.

CHAPTER XXXIV.

MISCELLANEOUS CUTANEOUS AFFECTIONS.[1]

THE diseases discussed in this chapter are:

1. Addison's Disease.
2. Dermatitis Herpetiformis.
3. Epidermolysis Bullosa Hereditaria.
4. Pemphigus.
5. Herpes.
6. Pityriasis Rosea.
7. Pityriasis Rubra Pilaris.
8. Raynaud's Disease.
9. Scleroderma.
10. Acrodermatitis.
11. Urticaria.
12. Urticaria Pigmentosa.
13. Lichen Urticatus.
14. Trachoma.
15. Synovial Lesions of the Skin.
16. Elephantiasis.
17. Fordyce's Disease.

Addison's Disease.—Ratera reports the cure of 2 cases of Addison's disease with *x*-rays. The first patient had a roentgenologic examination of the kidneys. Subsequent to this examination the constitutional symptoms and the pigmentation disappeared. The second patient received *x*-ray treatment, the exposures being confined to the kidney regions and consisting of monthly, cross-fire, intensive, filtered radiation. The general symptoms disappeared rather promptly. There was a gradual disappearance of the pigmentation.

Golobouine reports 1 case. The patient received daily exposures to the renal region for twenty-five treatments. There was improvement in all symptoms. The weight increased, the heart action became more regular, the digestive disturbances disappeared, and the bronzing became less marked.

Dermatitis Herpetiformis.—While few references can be found relative to the *x*-ray treatment of dermatitis herpetiformis, several authors have advised such treatment. Lapowski states that in 1 patient the eruption was made worse by applications of *x*-rays. The diagnosis, however, was disputed. H. Fox treated 4 cases with negative results. Years ago the author tried this treatment in 3 cases. The itching was relieved to some extent but the eruption was not materially benefited.

Epidermolysis Bullosa Hereditaria.—Berger reports that the skin in a case of this affection became more irritable as a result of roentgen-

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[1] For explanation of terms used in this chapter to express dosage see Chapters X and XIX.

ization. Lesions were more numerous after irradiation than before the treatment.

Pemphigus.—Weiss reports disappearance of vegetations under the influence of roentgenization in a case of pemphigus vegetans. Scholtz obtained temporary improvement with *x*-rays in a case of pemphigus foliaceus. The author tried *x*-rays and radium in 1 case of pemphigus foliaceus without benefit. Gilchrist gave seventy fractional *x*-ray treatments to a case of pemphigus of this type without benefit. *X*-rays were tried again at a later period with some benefit. Wise cured 1 case of chronic pemphigus with fractional *x*-ray treatment. There was no recurrence at the end of one year (verbal communication).

Herpes.—Pfahler reports a case of herpes simplex with almost continuous eruption for three years. After eight mild *x*-ray exposures the eruption disappeared and remained absent for nine months when it again appeared. Dermatologists search for and usually find the cause for recurrent herpes simplex. Newcomet, Schiff, Wickham and Degrais and others aver that small doses of radium and *x*-rays relieve the pain associated with zoster. Schamberg has found filtered *x*-rays of greater service than electricity for the persistent pain in some cases of zoster. (see "Radicular Roentgen Therapy" Chapter XXV).

Pityriasis Rosea.—Allen treated 3 cases of pityriasis rosea with *x*-rays. He thought that the eruption in each instance disappeared more rapidly than would have been the case under regular dermatological remedies. Blaschko reports the disappearance of an eruption of pityriasis rosea in a fortnight under the influence of *x*-rays. J. F. Auner, of Des Moines, in a verbal communication tells of a case of pityriasis rosea of one week's duration in which the eruption disappeared in one week after a single exposure of H¼ S. D. unfiltered.

The pathology of pityriasis rosea is such that one would expect roentgen therapy to be beneficial. The disease, as a rule, is very mild, it is self-limited and it usually disappears in a few weeks. Occasionally the affection is severe and it may last for two or three months. In such instances it would seem as though roentgenization might be of distinct value. The technic of application is the same as that recommended for generalized eczema, psoriasis and lichen planus.

Pityriasis Rubra Pilaris.—Pusey obtained improvement with large doses of *x*-rays in 1 case of pityriasis rubra pilaris of moderate severity. G. H. Fox noted that itching was arrested and that the infiltration was markedly lessened in 1 case treated with *x*-rays. H. Fox treated 1 case with disappointing results (modern technic).

Raynaud's Disease.—Newcomet has found *x*-rays useful in this disease. The ulcers heal more quickly and pain is lessened.

Scleroderma.—Several years ago there were a number of cases of scleroderma, to which *x*-rays had been applied, presented at the Manhattan Dermatological Society by Geyser, Oulmann, Weiss and

others. In a few instances there was some improvement. In most of the cases the results were negative. Belot cured 1 case and markedly improved several other cases of circumscribed scleroderma with large monthly doses over a period of several months. Pfahler found that the results of roentgen therapy in scleroderma were slight when compared to the time and energy expended. The author observed fairly rapid healing of long-standing ulcers, apparently as a result of a few mild *x*-ray treatments in a case of widespread scleroderma of the legs. There was no effect on the scleroderma.

It is obvious that scleroderma is exceedingly recalcitrant to irradiation. Excessive dosage may convert normal skin into a condition resembling scleroderma (Balzer and Monseaux, Solomon, Fournier and Barthélemy, Behrend, Hallopeau and Gadeau and many others). The end-result of scleroderma is often atrophy or sclerosis, which, also, may follow long-continued irradiation. For these reasons it is advisable to employ considerable caution when using *x*-rays or radium in the treatment of scleroderma. It is the author's opinion that irradiation is not indicated in this disease except, perhaps, in a few selected cases.

Acrodermatitis.—Bodin has found *x*-rays of service in "continuous suppurative acrodermatitis," a pyodermic eruption of the hands and feet.

Urticaria.—Lawrence claims the cure with *x*-rays in two weeks of a case of severe generalized urticaria of long standing. It is the duty of the physician to locate and remove the cause of urticaria. This can be usually accomplished. In cases where it is impossible to cure the disease and the patient is suffering severely from the itching, *x*-rays may possibly be of service. There has been no personal experience.

Urticaria Pigmentosa.—Török and Schein report a complete and permanent cure of a case of urticaria pigmentosa by means of *x*-ray treatment. The exposures were followed by erythema. In a case treated by Jacob the patient was given three exposures at weekly intervals. There was no reaction. The eruption did not disappear, but the lesions ceased to swell when irritated and there was no factitious urticaria. Itching was absent and no new lesions developed. The relief lasted for three months at which time all the symptoms returned. A second course of treatment again effected relief. The outcome of the case is unknown.

Lichen Urticatus.—Lawrence reports good results in obstinate cases of lichen urticatus with small doses of *x*-rays.

Trachoma.—Trachoma is an opthalmological disease but it is of some interest to the dermatologist. Excellent results, even permanent cures, may be had with both radium and *x*-rays. In the author's experience beta rays of radium are more efficacious and they are more easily applied than are *x*-rays. The literature on this subject is becoming rather voluminous. Stephenson and Walsh, and Mayo

observed good results with x-rays in 1903. Vassioutinsky, Schamberg, Newcomet, Pusey, and Krall and many others, have testified to the efficacy of x-rays in this disease. Zelenkovsky, Darier, Pusey and others report good results with radium. Abbe obtained permanent cures in 10 cases of vernal catarrh with radium. The author's results have been splendid in the few cases treated, both in vernal catarrh and trachoma. In each instance the diagnosis was made by an ophthalmologist. Most of the cases were diagnosed as vernal catarrh.

FIG. 249.—Synovial cyst of the skin. (Courtesy of Dr. R. L. Sutton.)

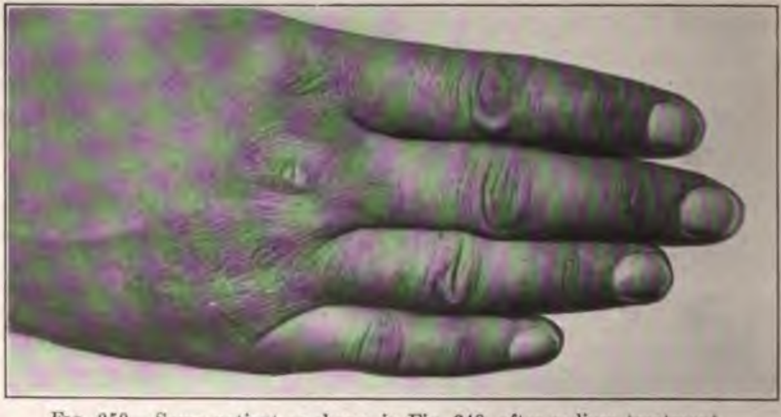

FIG. 250.—Same patient as shown in Fig. 249, after radium treatment. (Courtesy of R. L. Sutton.)

Technic.—The upper lid may be inverted and an unscreened, flat radium applicator placed in contact with the mucous membrane. Radium can be applied to the lower lid by pulling the cheek downward with the fingers. The artificial ectropion can be maintained by attaching one end of a strip of zinc plaster to the lower eyelid and the other end to the neck under the mandible. Before fastening the lower end of the zinc plaster the cheek should be pulled downward and the neck upward. Pusey holds the everted lid in position with special lid forceps which not only holds the lid in position but also protects the eye. For a full-strength applicator, unscreened, the dose is from three to five or even ten minutes at intervals of three or four weeks. No protection is necessary for the eye.

The preparation is the same for the application of *x*-rays. A diaphragm made of lead foil should be used to protect all but the affected areas. If the shield irritates the eye, a drop of cocaine solution will overcome the difficulty. The dose is H½ to H¾ S. D., unfiltered, once a month. If the disease responds to irradiation not more than one, two or three treatments will be required. In recalcitrant cases one must be careful not to injure the eye. It has been found, however, that the eye will stand long-continued irradiation without apparent injury.

Synovial Lesions of the Skin.—Hyde and Ormsby cured several cases of synovial lesions of the skin with *x*-rays. Lingenfelter reports a cure in 1 case. Sutton cured 1 patient with 1 application of unfiltered radium. Ormsby's cases were treated fractionally, not more than ten or twelve mild, unfiltered applications being required. In Lingenfelter's case two fairly strong exposures at intervals of eleven days sufficed for a cure. The lesion had resisted solid carbon dioxide and other methods of treatment. In Sutton's case the lesion disappeared as a result of forty milligram hours of unscreened radium. MacKee and Andrews cured 1 case with one cross-fire, unfiltered *x*-ray treatment. It seems that irradiation is specific for this recalcitrant affection.

Elephantiasis.—Mascat reports the cure of 3 cases of pseudo-elephantiasis (streptococcic) with *x*-rays. Sorel and Soret, and Snow report benefit in this type of elephantiasis. These are old references. There is nothing in modern literature relative to the *x*-ray or radium treatment of any type of elephantiasis.

Fordyce's Disease.—Pinch cured 1 case and improved another case of Fordyce's disease with radium.

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CHAPTER XXXV.

THE MEDICO-LEGAL RELATIONS OF ROENTGEN THERAPY AND RADIUM THERAPY.

THE purpose of this chapter is to show the connection between the law and the practice of medicine in some particular matters. The principles outlined and illustrations used are to show what the writer believes to be the general legal opinion in the United States, with some variations in the same. With our system of State and Federal courts a contrary opinion or different theory may be the law where the reader resides, for the law in one State or jurisdiction does not necessarily control or agree with that of another. In some instances no opinion general or otherwise has been found, or the principle is very unsettled; in such cases the author has stated his own opinion.

LEGAL REGULATION OF MEDICAL PRACTICE.

Public policy requires regulation of the practice of medicine as it does of the law, to prevent those unable or unwilling to attain a certain degree of skill from practice and to keep those admitted up to the standard. Any who attempt to practice without license and authority are usually guilty of a crime and those who are authorized assume certain legal obligations toward their patients and the community. In other words a physician is liable in damages for a breach of these obligations and in extreme cases even liable to imprisonment. New York provides by statute that any person who offers or undertakes to practice medicine, who has not received a license from the State permitting him to do so, is guilty of a misdemeanor.

Malpractice.—Malpractice may be defined as wilful acts, negligent acts, unskilful treatment or acts prohibited by statute, by a physician or surgeon, resulting in injuries to or death of the patient.

Criminal negligence usually means such negligence as would be inferred from actions which are reckless or indifferent to results.

Medical Practitioners.—"A physician is one lawfully engaged in the practice of medicine. It includes all who practice physic or surgery and is not limited to any one school of practitioners," 30 Cyc. 1544.

"A surgeon may be said to be a physician who treats injuries, deformities, disorders," 30 Cyc. 1546. It would also include treatment of disfigurements or other physical conditions "by manual operations and the use of surgical instruments and appliances."

The New York statute defines the practice of medicine as follows:

"A person practises medicine within the meaning of this article, except as hereinafter stated, who holds himself out as being able to diagnose, treat, operate or prescribe for any human disease, pain, injury, deformity, or physical condition, and who shall either offer or undertake by any means or methods, to diagnose, treat, operate or prescribe for any human disease, pain, injury, deformity or physical condition." It is said in 219 N. Y. 98, "the New York statute regulating medical practice applies to every means and method that could . . . be used or claimed to be used to relieve or cure disease and infirmity unless excepted by the statute."

An *x*-ray operator, therefore, who offers or undertakes the application of *x*-rays or radium to any human being, either for diagnostic or curative purposes is practicing medicine, and he must be licensed.

"Superfluous hair on the face is a 'deformity' within the meaning of the New York State Public Health Law, and one who, not being a licensed and registered physician, holds herself out as being able to successfully treat such a deformity and undertakes to treat it with an electric needle, violates the statute regulating the practice of medicine and under the statute she is guilty of a misdemeanor and cannot recover for services rendered in giving such treatments," 102 N. Y. Misc. 97. This case was overruled in 184 Ap. Div. 953, on the ground "that the evidence did not warrant the lower court deciding that the treatment administered constituted the practice of medicine." There was a dispute as to whether the operator had "held herself out" as set forth in the New York statute. Certainly a regularly licensed physician and surgeon or one associated with him "holds out" as such.

"Liability under a statute prohibiting the practice of medicine without a license is not affected by the fact that the operations were performed and the medicines were administered under the direction and charge of a licensed physician and surgeon. 30 Cyc. 1564."

RELATION BETWEEN PHYSICIAN AND PATIENT.

In the contract between physician and patient there are always necessary in order for it to be binding the essentials of: legality of object, a mutual understanding, agreement and obligation as to the subject matter, parties competent to contract, and a valuable consideration, which consideration need not be money.

The physician is obligated to use a certain degree of care and skill; the patient to follow his physician's directions.

Requisite Skill and Care.—"A physician or surgeon undertaking the treatment of a patient is only required to possess and exercise that degree of skill and learning ordinarily possessed and exercised by the members of his profession in good standing, practising in similar localities, and it is his duty to use reasonable care and diligence in the exercise of his skill and the application of his learning, and to act

according to his best judgment," 30 Cyc. 1570. "A specialist will be held to the special degree of skill and knowledge possessed by physicians who are specialists in the treatment of the disease in which he specializes," 30 Cyc. 1571. "In determining the degree of learning and skill required, regard must be had to the state of medical science at the time," 30 Cyc. 1572. It is said in 155 N. Y. 201, he is "bound to keep abreast of the times."

This standard of skill and action continues throughout the relation of physician and patient and is required as well in the examination, diagnosis, selection of and application of treatment, as the following will show:

"It is the duty of a physician to act with the utmost good faith toward his patient, and if he knows that he cannot accomplish a cure, or that the treatment adopted will probably be of no benefit, it is his duty to advise his patient of these facts and if he fails to do so he is guilty of a breach of duty," 30 Cyc. 1579, citing from 62 Minn. 146, "Where a physician in charge of a sanitarium represents to an invalid, without knowing the truth or falsity of the representation, that if the latter will take treatment at the sanitarium he can be cured, and the invalid relies thereon, and enters the sanitarium, but is not cured, the physician is liable in an action for deceit."

"A wrong diagnosis of a case resulting from a want of skill or care on the part of a physician and followed by improper treatment to the injury of the patient, renders the physician liable in damages," 30 Cyc. 1575. "A general practitioner will not be held liable for making a wrong diagnosis of a very rare disease which can only be detected by a skilled expert." In this case glaucoma was the disease, 30 Cyc. 1575. "A physician entitled to practice his profession and possessing the requisite qualifications and applying his skill and judgment with due care is not ordinarily liable for damages consequent upon an honest mistake or an error of judgment in making a diagnosis, in prescribing treatment, or in determining upon an operation, where there is reasonable doubt as to the nature of the physical conditions involved, or as to what should have been done in accordance with recognized authority and good practice," 30 Cyc. 1578. "Although a physician may have exercised a proper degree of skill and care in his treatment of a case, still if he fails to give the patient or his attendants proper instructions as to the care and attention best calculated to effect a cure he is guilty of negligence for which he may be held liable," 30 Cyc. 1577. "The welfare of the citizens of a State and therefore of a State itself, demands that those persons practicing medicine and surgery shall be able and careful. So in the absence of a statute the common law holds every physician or surgeon answerable for an injury to his patient resulting from want of the requisite knowledge and skill, or the omission to use reasonable care and diligence or the failure to exercise his best judgment. This rule is elementary and has its foundation in most persuasive considerations of

public policy. Its purpose is to protect the health and lives of the public, particularly of the weak or credulous, wary or unwary, from the unskilfulness or negligence of medical practitioners, by holding them liable to respond in damages for the result of their unskilfulness or negligence," 21 R. C. L. 379–380. "The rules governing the duty and liability of physicians and surgeons in the performance of professional services are applicable to manipulators of *x*-ray machines," 21 R. C. L. 386.

A judge in the New York County Supreme Court in 1918, in an action to recover from a roentgenologist and dermatologist of high standing for injury alleged to have been inflicted by alleged negligence in applying roentgen rays in the treatment of superfluous hair, charged the jury in effect "that a physician is not held to use unusual care, diligence and skill but only the average skill that is commensurate with the general standard of the profession in similar localities at the time of the acts alleged." However, the court added: "That in the case of a specialist the standard would be that ordinarily possessed by practitioners devoting special attention and study to the same branch in similar localities, having regard to the present state of medical science."

In this same action the judge instructed the jury "not to take the opinions of the expert witnesses necessarily as conclusive evidence, but merely as an aid to arrive at conclusions of fact. That it was necessary that the plaintiff show by a preponderance of evidence that the defendant had been negligent and unskilful in his selection and administration of treatment or the plaintiff could not recover. That a physician was not an insurer of good results and that if ill results followed treatment he would be held to respond in damages only in case he had been negligent and unskilful in the selection of the form of treatment and in its administration."

"A surgeon employed to treat a case professionally, is under an obligation to exercise the ordinary care and skill of his profession, in the light of modern advancement and learning on the subject, and that he will indemnify the patient against any injurious consequences resulting from his want of ordinary skill, care and diligence in the exercise of his employment. That for the operation and subsequent necessary treatment he will use due care and diligence to the end that a recovery may be had. This obligation exists as long as the relation of patient and physician and surgeon continues. No promise to effect a cure is implied but due diligence, care and ordinary skill are implied undertakings. It is the duty of the surgeon to exercise due diligence, care and ordinary skill, not only in performing an operation, but also in the subsequent necessary treatment following such operation, unless the terms of employment otherwise limit the service, or the patient gives the surgeon notice, that he will not or cannot afford the subsequent treatment," 67 Ohio St. 106.

The doctrine announced in this last case is very plain and practical,

so that both surgeon and patient will have their respective interests abundantly safeguarded. The doctrine is promotive of the exercise of reasonable skill, care and treatment by the surgeon, not only at the specific time of the operation, but also during the subsequent period of treatment necessary to a reasonable and substantial recovery. The patient relies almost wholly on the judgment of the surgeon, and under the usual circumstances of each case is bound so to do, and if the injury is not reduced, and a normal condition restored, as fully or as speedily as expected, the patient is still at liberty to rely on the professional skill, care and treatment to complete such recovery so long as the surgeon continues his employment with reference to the injury. Physicians and surgeons exercising reasonable care and skill need have no fear of it. Reckless and careless physicians and surgeons should be kept in fear of this doctrine.

The law should not impose on the patient a duty that he can know only through expert knowledge which he does not possess, but as to which he is compelled to accept the judgment of his physician or surgeon. The surgeon should have all reasonable time and opportunity to correct the evils which made the operation or treatment necessary, and even reasonable time and opportunity to correct the unavoidable mistakes incident to even skilled surgery. The doctrine announced here is conducive to that mutual confidence that is highly essential in the relation between surgeon and patient.

In Cal. 174 Pac. Rep. 654, the Supreme Court says: "The law on the subject of care and skill required of physicians in the treatment of patients is well settled;" quoting "A physician and surgeon by taking charge of a case, impliedly represents that he possesses, and the law places upon him the duty of possessing, that reasonable degree of learning and skill that is ordinarily possessed by physicians and surgeons in the locality where he practices, and which is ordinarily regarded by those conversant with the employment as necessary to qualify him to engage in the business of practicing medicine and surgery. Upon consenting to treat a patient, it becomes his duty to use reasonable care and diligence in the exercise of his skill and the application of his learning to accomplish the purpose for which he was employed. He is under the further obligation to use his best judgment in exercising his skill and applying his knowledge," from 155 New York 209. Further quoting from 187 Mich. 330; 153 N. W. Rep. 695: "The difficulties and uncertainties in the practice of medicine and surgery are such that no practitioner can be required to guarantee results, and all the law demands is that he bring and apply to the case in hand that degree of skill, care, knowledge and attention ordinarily possessed and exercised by practitioners of the medical profession under like circumstances." It further quotes from 27 N. H. 474; 59 Amer. Dec. 388: "It is never enough to show that he has not treated his patient in that mode, nor used those measures, which in the opinion of others, even medical men, the case required,

because such evidence tends to prove errors of judgment, for which the defendant is not responsible, as much as the want of reasonable care and skill, for which he may be responsible." The rule is said in a New Jersey case reported 12 N. J. L. J. 269, to be: "The law requires of a physician that degree of knowledge and skill which is usual in the grade of the profession which he occupies, and in which he was employed in the particular case."

In the case of N. C. 101 S. E. Rep. 99, a consulting physician, failing to make a clinical diagnosis, based his diagnosis on a positive Wassermann reaction. The plaintiff patient brought forward evidence to show that the diagnosis was erroneous, but failed to prove negligence. In affirming a judgment of nonsuit the Supreme Court says that, "the law governing the liability of a physician to his patient is well settled. While there is an implied contract that the physician or surgeon who undertakes to treat a patient will use all known and reasonable means to accomplish the object for which he is called to treat the patient, and that he will attend to the patient carefully and diligently, there is no guaranty that he will cure him, or that he will not commit an error of judgment. The law implies only that he not only possesses, but that he will employ in the treatment of the case, such reasonable skill, care and diligence as are ordinarily exercised in this profession. But a physician or surgeon possessing the requisite qualifications and applying his skill and judgment with ordinary care and diligence to the diagnosis and treatment of a patient, is not liable for an honest mistake or error of judgment in making a diagnosis or prescribing the mode of treatment, where there is ground for reasonable doubt as to the practice to be pursued." In this latter case the patient had been sent by his family physician for treatment to the defendant's hospital.

"It is well settled that the degree of learning and skill which a physician or surgeon is required to possess and exercise is that degree of skill and learning ordinarily possessed and exercised by members of his profession in the same line of practice in that locality. The evidence in the record justifies the finding that the use of *x*-rays in the diagnosis and treatment of human ills is recognized and practiced by the medical profession. Such being the case, we see no reason why a different rule should apply to practitioners in this line than is applied to other practitioners," 35 App. Cases. Dist. Col. 57.

In roentgenological work the required standards of technic change from year to year. In each action a comparative standard is formulated for the jury by the expert witnesses. It is for the jury to weigh the evidence given by the expert witnesses on both sides, to decide upon a standard and to determine if the defendant possessed and used skill in keeping with the standard. The burden of proof is on the plaintiff, but the defendant must meet this proof with proof sustaining his own contentions.

The necessity of having accurate data and a well-prepared case is

shown in Va. 96, S. E. Rep. 360, *Jour. Am. Med. Assn.*, lxxii, No. 15, p. 1100, where the Supreme Court of Appeals, in a lengthy opinion, affirms a judgment in favor of the plaintiff for damages alleged to have been occasioned to him by the alleged malpractice of the defendant physician in the treatment with *x*-rays of eczema with which the legs and ankles of the plaintiff were affected. The court says "it should be borne in mind that the case involved two standards of professional skill and care by which the evidence as to the competency and the conduct of the defendant was to be measured. One standard has reference to the technic or mechanical operation of the *x*-ray apparatus and the other standard has reference to the possession and use of the professional skill and care incumbent on the defendant with respect to the diagnosis and treatment of the disease of the plaintiff in matters other than the mere mechanical operation of the apparatus. The two standards mentioned both involved, in this case, the highly specialized art of the treatment of the disease of the plaintiff by *x*-rays; and so far as they did so, expert testimony before the jury fixing such standards was essential to the support of the verdict of the jury, since otherwise the jury, to the extent of the questions involving such specialized art, would have no standard in mind by which to measure the other facts proved in the case. Now, as to the mechanical standard of skill and care, there was no expert evidence in the case except the testimony of the defendant and of other expert witnesses for the defendant; but there was sufficient evidence in the case, when measured by the mechanical standard fixed by the testimony of the defendant, to support the verdict of the jury. . . It is deemed sufficient to mention only the following details of such evidence: There was evidence in the case to the effect that the defendant did not keep an accurate record of the *x*-ray treatment or any record of the exact dose of *x*-rays applied in the several treatments therewith; that if the standard dose only had been applied, it was extremely improbable that any bad results would have been caused. . . The cross-examination of the defendant tended to show that his memory of the dose applied by him in the several treatments was not to be relied on. There were inconsistent statements made by the defendant at different times as to his opinion of the causes of the bad result; and there was other evidence to support a conclusion of the jury that the dose in fact applied was not in accordance with the mechanical standard fixed by the expert testimony of the defendant himself. It was true that such testimony did not show that the bad result might not have happened without fault of the defendant, but there was sufficient of such evidence, the credibility and weight of which was for the jury, tending to show that the bad result was more probably due to negligence or lack of skill on the part of the defendant as charged. This degree of proof is all that is required of a plaintiff in a civil case. He is not required to exclude by his proof the possibility of the result complained of having been

due to causes for which the defendant is not responsible. . . The cause of the injury being the *x*-rays was, however, but one element of fact in the case. As the jury was properly instructed, if the defendant exercised ordinary care and skill in the premises, the plaintiff was not entitled to recover damages, although the injuries complained of were caused by the *x*-ray treatment; and the question still remained whether the defendant did or did not exercise such care and skill. The court thinks there was sufficient evidence in the case, when measured by the general professional standard as well as by the mechanical standard of skill and care, to support the verdict of the jury. . . It was correct to say that the standard which made it the duty of the defendant to make preliminary tests and examinations before subjecting the patient to *x*-ray treatment had to be tested by ascertaining if other like specialists in good standing, in the same or similar localities as the defendant, would have been guilty of the omission to make such preliminary tests and examination, which test had to be applied by measuring the evidence, as it might be introduced in the trial by the standard fixed by the testimony of experts on the subject, since the standard mentioned involved a highly specialized art of treatment. Failure to warn of danger in the treatment was not *per se* negligence." In this case the verdict was for the plaintiff.

The law considers that one of the fundamental requisites of the medical practitioner who uses the roentgen rays is the ability to make properly a skilful and careful diagnosis of the trouble of a patient and if the practitioner errs in that diagnosis through lack of proper skill or care, he must answer to the patient for the injury caused by the erroneous diagnosis just the same as he must answer for the application of improper treatment. If by the exercise of proper care and skill a practitioner ought to find out that a person is unusually susceptible to injury by the roentgen rays and fails to do so, or after making the discovery fails to warn the patient of the danger, the practitioner is liable if he causes the patient injury which otherwise would not have happened. And it would be unwise and unsafe to follow the diagnosis of any other medical practitioner unless one's own careful and skilful diagnosis led to the same opinion or if it differed without a consultation with the other, especially if the patient had been sent by him, although the following case seems to hold to the contrary.

The question of idiosyncrasy is likely to be one of diagnosis. In the case of 35 Appeal Cases Dist. Col. 57, the plaintiff asked the court to instruct the jury to the effect that "if the evidence shows that there is possibility that the patient might have been injured by the *x*-rays due to some idiosyncrasy which would make her more susceptible to the influence of the *x*-rays regardless of the skill and care used; but which possibility or predisposition the physician knew or should have known, then it was the duty of the defendant to so

inform the plaintiff." The Court of Appeals said: "There is nothing in the record to justify the inference that the condition of the plaintiff when the defendant subjected her to the *x*-ray exposures, was such as to render her peculiarly liable to injury. Having been under a surgeon of recognized ability, and having been sent to the defendant by such surgeon for the purpose named, we think the defendant, in the absence of anything warranting a contrary conclusion, was justified in relying upon the judgment of the surgeon."

In 123 Va. 113, 96 S. E. REP. 360 Sup. Court of Appeals heretofore quoted, the plaintiff claimed that "some people are more susceptible to the influence of the *x*-rays than are other persons and it was the duty of the defendant to make tests and examinations to determine the susceptibility of the plaintiff and to warn him of his susceptibility." The court says "there was no evidence tending to show that the plaintiff was more susceptible to injury by the *x*-rays than others. Some experts testify that a person of fair complexion is more susceptible. However, the plaintiff is of dark complexion, hence the fifth count cannot be supported."

Acknowledged Want of Skill.—It is said in 30 Cyc. 1581, citing as in point 88 Hun N. Y. 200, that "if a practitioner frankly informs a patient of his want of skill, or the patient is in some other way fully aware of it, the latter cannot complain of the lack of that which he knew did not exist." In the case cited the family physician on being called in to examine the patient announced that the wound was of a serious nature and character and that he did not regard himself as sufficiently experienced in surgery to properly treat the case. He advised the family of the patient, who was about seventeen years old, to call in the services of a more experienced and skilful surgeon. This was done and the two physicians together treated the patient for about a week when another doctor was called in. The first two physicians were sued for damages for malpractice and a verdict was given against them although the jury was charged by the trial court in the language quoted above, and the verdict was sustained on appeal. The appellate court recognized the above rule but stated that the jury having been so instructed and having found for plaintiff it must be assumed that it found the facts and circumstances did not warrant the application of the rule.

"It is the duty of a patient to coöperate with his physician and conform to the necessary prescription and treatment, and follow all reasonable instructions given." 30 Cyc. 1579.

Release of Liability.—While the writer has been unable to find a case exactly in point, it is safe to say that there can be no legally binding agreement with a patient not to hold a medical practitioner for negligence; that is, before the negligence occurs.

The reason of this is that it would be against public policy to permit such contracts. "The contract is *quasi public*," 67 Ohio St., at p 124, citing 64 Me., 305. The weight of legal opinion holds it so t

in the case of such contracts between common carriers and their passengers for hire and between employees and employers, 3 Thom. on page 744. In 71 L.R.A. (N.S.) 537; 184 N. Y. 379, in a case holding it against public policy for an employee to contract to relieve the employer from liability for injuries due to the employer's negligence, it is said "The State is interested in the conservation of the lives and of the healthy vigor of its citizens, and if employers could contract away their responsibility... it would tend to encourage on their part laxity of conduct in, if not an indifference to, the maintenance of proper and reasonable safeguards to human life and limb." As was said in a railroad case in 24 N. Y. 196, "The principle therefore is that parties cannot contract that they themselves may with impunity be guilty of wilful misconduct or of that degree of recklessness which is its equivalent."

If there is an injury or claim of such, the civil remedy for damages may be waived, but if gross to the degree of criminal negligence, the crime cannot be waived. Each legal jurisdiction has particular practices prohibited and each must therefore be studied in a specific case.

Express or Implied Understanding.—There should be a complete and definite understanding and agreement as to the purpose of the contract by both the patient and the physician. It is not usually practicable for the agreement to be reduced to writing and signed by the parties, but it would save much litigation and protect many defendants if it were. Avoid leaving it to implication by either party.

In the absence of such writing the agreement should be as definite as possible and the careful and wise practitioner will keep exact dated notes and photographic records when possible, of conditions of the patient before, during and after his examination, diagnosis and treatment.

It should be made plain that the physician will do as well as he can with the condition presented by the patient, but that there is no certainty of result one way or the other, for the law does not call upon him to insure results, unless he has expressly undertaken and assured results that will be successful or satisfactory. Such express assurances should always be in writing or otherwise serious litigation is likely to result from misunderstanding between the parties.

In any event it is unwise to confine the understanding to one specific treatment or method to be used, for a contract once made may not be modified by one party without the complete knowledge and consent of the other. In this type of contract, latitude should be reserved by the practitioner to enable him to use different or improved methods if the circumstances warrant. At the same time the patient should be held to the strictest observance of directions.

Consent to Treatment.—Although it may not be practicable or necessary in great emergencies before undertaking the diagnosis or treatment of an infant, a married woman, or a person suffering from some temporary or permanent disability of the mind or otherwise unable to speak

for self, it is better to get the consent of the parents or person in charge of the patient, as well as when there is no emergency. An interesting case showing how claims arise against and must be defended by physicians is that of 83 N.J.L. 20. Here the plaintiff applied to the defendant physician to operate upon a rupture in his left groin that had been unsuccessfully operated on two years before. On learning that the plaintiff was a poor man, the doctor engaged to operate free of charge. At the time fixed for the operation the plaintiff was placed under the anesthetic by two assisting surgeons who, when the operating surgeon came into the operating room, directed his attention to a rupture they had just discovered in the patient's right groin and which upon employment of diagnostic tests was determined to be a serious menace to the patient and likely to cause his death should strangulation occur. The surgeon thereupon operated upon the more serious rupture intending to operate also upon the other which he was prevented from doing by the patient's condition under the anesthetic. The patient upon being informed that the operation would be completed on a following day apparently acquiesced, but later declined to go on with the operation and brought civil action for damages against the defendant for assault and battery. The jury in the lower court found that the defendant had performed an operation on the plaintiff without his consent and rendered a verdict of $1000 against him. On appeal the Supreme Court in setting aside the verdict held: "The conclusion we are led to is that when a person has selected a surgeon to operate upon him and has appointed no other person to represent him during the period of unconsciousness that constitutes a part of such operation, the law will by implication constitute such surgeon the representative *pro hac vice* of his patient and will, within the scope to which such implication applies, cast upon him the responsibility of so acting in the interest of his patient that the latter shall receive the full benefit of that professional judgment and skill to which he is legally entitled. Such implication affords no license to the surgeon to operate upon a patient against his will or by subterfuge, or to perform upon him any operation of a sort different from that to which he had consented or that involved risks and results of a kind not contemplated. As to such matters the rule in question submits nothing to the judgment of the surgeon, who as the implied representative of his patient can under such implication truly represent him only in so far as he gives to him the benefit of his professional wisdom within the general lines of the curative treatment agreed upon between them; unless of course a wider discretion has been accorded him. Within such general lines, however, much is necessarily left to the good judgment of the operating surgeon, just how much will depend upon the circumstances of the individual case."

Physician not an Insurer.—A perusal of various court opinions contained in this chapter will show that a physician, in absence of contract to the contrary, does not insure against injurious results nor for success

of treatment. He simply insures proper care and skill. In 138 Mo. App., 231, for malpractice consisting of alleged "negligent, rash, unprofessional, unskilful and ignorant *x*-ray treatment," the plaintiff received a verdict for $3500 in the lower court. The appellate court reversed the decision and remanded for new trial. The plaintiff alleged "that she was suffering from 'some' ailment which caused her to consult the defendant physician; the defendant pronounced the ailment as hardening of the right lobe of the liver and proposed to treat the plaintiff for the ailment with the *x*-rays; that defendant so treated the plaintiff with *x*-rays, that the right side of her abdomen for the space of more than a foot in diameter was blistered and became raw and sore." The court instructed the jury to determine: "was the *x*-ray treatment given to the plaintiff by the defendant in accordance with the ordinary and established practice of the medical profession for treatment of the disease from which the plaintiff suffered." The defendant had asked the court to instruct the jury: "that the defendant as a physician should not be held as an insurer of the success of treatment by the *x*-ray process or that it would not be attended by unexpected results; and that the defendant was only required to have the necessary learning and experience to give the treatment in a careful and prudent manner." The court refused to so instruct the jury. The Court of Appeals held, "It is difficult to say whether or not the plaintiff bases the case on the charge that the *x*-rays were not the proper method of treatment for her ailment,—or the charge that the defendant was negligent and unskilful in the application or both. Unless the issue of fact is clearly: was the defendant negligent or unskilful in prescribing such. . . instructions to the jury as requested by defendant as heretofore stated were proper and should have been given. However, if that issue of fact is clear then the said instructions should have been given with additions as to the negligence and unskilfulness in prescribing such treatment at all; for a physician might be fully equipped in learning, skill and care to use the *x*-rays and yet use them in a case where a prudent physician would not have adopted them as a remedy. A physician is not to be held for an honest error of judgment. He is only required to give his patient his diligent attention and best thought and on prescribing, administering or applying treatment, to use that care, skill and prudence that an ordinarily capable doctor would use in the same or like situation and condition or circumstances. It is also certain that the defendant is not an insurer of the success of any kind of treatment which he may prescribe in the absence of a contract to the contrary."

Duration of Treatment.—It is well when undertaking a treatment to consider and agree as to the extremely important feature of time. If no period of time is agreed upon to complete the services the law will imply a reasonable time. It would seem best to agree for not less than a certain space of time and for a sufficient time in addition to complete the treatment of the condition existing at the expiration

of that time. "When a physician is engaged to attend a patient without limitation of time he can cease his visits only with the consent of the patient or on giving timely notice, or when the patient no longer requires medical treatment," 15 N.Y. Supp., 675, cited in 30 Cyc. 1574.

Associates and Assistants.—A physician's assistants or associates will be held to the same degree of skill and care stated and he may be held liable for not exercising care in their selection. "A physician is responsible for an injury done to a patient through the want of proper skill and care in his associate who is a partner or assistant or apprentice," 30 Cyc. 1581. This rule will probably also hold for his own nurses and technicians. "There are situations where a physician will be held liable for injury caused by no fault of his own but by the fault of another person. This liability is based upon the simplest principles of agency. A physician or surgeon may be liable for the negligence or default of his medical assistants, nurses, or other employees or servants," 21 R.C.L. 393. This is confined, of course, to acts done while working under his directions or to those acts within the scope of the agent's duty. An interesting case is that of 58 N.J.L. 193, where a physician promised the plaintiff, after examination of his wife, that he would attend her at her confinement which he stated would not be for several days. He then left the city, but before his return she was confined. The plaintiff telephoned the physician's house for him to come at once and in response to this message another doctor arrived who stated that he represented the first physician. He proceeded and took charge of the case. The child died shortly after being born, and the first physician was sued for alleged injuries to the wife resulting from the child's death. The Court of Errors and Appeals held: "The two doctors were each of them practicing physicians, having no business connection with one another, except that one was attending the patients of the other while he was temporarily absent; even if it be admitted, therefore, that he was employed by the other to attend the wife, that did not render the other doctor liable for his neglect or want of skill in the performance of this service . . . for a party who follows a distinct and independent occupation of his own, is not responsible for the negligent or improper acts of the other." 30 Cyc. 1581 is to the same effect.

Compensation.—"In the absence of an express agreement, the right of a physician to be compensated for his services does not depend upon the measure of his success in effecting a cure by the means employed, but upon diligent exercise under his employment, of the skill which commonly pertains to his profession. Such services are regarded as beneficial in a legal sense and the right to adequate compensation arises upon their rendition whether the outcome be in fact beneficial to the patient or otherwise," 30 Cyc. 1594.

Merely because advice or treatment is given free, or is unpaid for will not relieve the practitioner of liability. He is not obliged to

continue except to carry the patient beyond danger, if not paid as and when agreed and it is well if possible to have the time and amount of payment agreed; but he cannot in the absence of such an agreement without much risk, stop a treatment at a time that will expose the patient to serious results. "The fact that a physician or surgeon renders his services gratuitously does not absolve him from the duty to use reasonable and ordinary care, skill and diligence," 30 Cyc. 1573. The case of 47 N.Y. 186, was an action against a physician for malpractice in treating the eyes of the infant plaintiff. At the trial the question was asked of the plaintiff's father: "Has the defendant ever called upon you to pay for services in that matter?" Answer, "No, sir; he has never presented any bill or asked for any pay." The defendant objected to this question on the ground that it prejudiced the jury in favor of the plaintiff. The trial court overruled the objection and admitted the testimony. The jury found a verdict for the plaintiff for $2000. The defendant appealed, contending that the court erred in admitting this evidence. On appeal the Court of Appeals held, "Whether the physician had presented any bill or asked for any pay for services is entirely foreign to the issue. It did not legitimately prove, or tend to prove, either want of care or skill in the treatment of the plaintiff by the defendant. The evidence was improper and its admission under objection error for which the judgment will be reversed." To the same effect is 40 Ill. 209, which was an action against a surgeon for malpractice. The court instructed the jury: "that if the defendant had held himself out as a physician, he was liable for whatever damage may have occurred to the plaintiff by reason of any want of skill or care on his part whether he charged fees or not." Judgment was for the plaintiff. Defendant appealed. The appellate court held "The judge stated the responsibility of a physician too strongly in his instructions to the jury. It is true that a physician is liable even though he does not receive fees, but he must be held to only ordinary and not the highest degree of skill and care. By the use of the word 'any' in his instructions the judge implied that the physician was bound to use the highest skill and care." Judgment reversed. New trial ordered. In 88 Iowa 320, it is said, "We can discover no good reason why the degree of care to be used by the physician or surgeon should be less in case his services are gratuitously rendered." "If a physician undertakes the treatment of a patient unable to compensate him, his liabilities for negligence or malpractice are the same as in the case of any other patient," 30 Cyc. 1581.

Many physicians erroneously believe that they cannot be sued for malpractice if the treatment is carried out in a hospital or dispensary and especially if no fee is charged or if the institution collects and retains the fee. We have seen that gratuitous services do not effect a physician's liability. It is fairly well established in all jurisdictions that being engaged by an institution in a professional capacity, salaried or unsalaried, does not necessarily alter a physician's liability insofar

as concerns negligence or skill. It is also the weight of opinion that charitable hospitals are not liable for the negligence or misconduct of their doctors or employees. If a dispensary patient or a patient in a charitable hospital is injured by the *x*-rays and it can be proved that the injury was caused by the negligent or unskilful application of the *x*-rays by a physician or his agent (assistant, nurse or lay technician) the physician may be liable to respond in damages. There are numerous instances of this kind where a surgeon or his assistant or a nurse has left an instrument or piece of gauze in the abdomen after a surgical operation. In the case of U. S. 256 Fed. REP. 196, Jour. Am. Med. Assn., October, 1919, p. 1306, a visiting surgeon on the staff of a public hospital was compelled to respond in damages to the extent of $7709.57 for the alleged negligent treatment of deranged bones of the legs or bow legs. The patient's legs had been placed in a plaster cast by the surgeon. The patient was then attended by the hospital interne. It was alleged that the pressure of the cast had caused an injury that necessitated amputation of a leg. There was contradictory evidence as to whether the surgeon interfered with the interne's treatment. "A physician employed by a city to treat patients at the city almshouse is liable to one of such persons who is injured through the physician's negligence, although there is no contractual relation between such patient and the physician," 30 Cyc. 1581.

"A hospital created and existing for purely governmental purposes and under the exclusive ownership and control of the State is not liable for injuries to a patient caused by the negligence or misconduct of its employees," 21 Cyc. 1108. "A private hospital which is in its nature a charitable institution is not liable in damages to patients for the negligence or misconduct of its officers or employees," 21 Cyc. 1111. The Supreme Court of Washington, 169 Pac. REP. 828, affirmed a judgment that dismissed an action brought by the plaintiff, a child, to recover damages alleged to have been sustained by reason of negligence of the hospital nurses, and followed its rule in a former case to the effect, "a charitable institution is not liable for the negligence of a physician whom it employed, but is responsible for want of ordinary care in selecting him." The Alabama Supreme Court, 191 Ala. 572, 68 S. REP. 4, however, gives a contrary opinion in a case of a hospital nurse at the same time stating that the court recognizes the weight of authority in the United States is to the contrary. In the case of U.S. 247 Fed. REP. 639, the United States Circuit Court of Appeals, Third Circuit, refused to hold a charity hospital responsible for negligence and unauthorized conduct on the part of a nurse who administered poison instead of a cathartic to a patient. In the case of Wyo. 160 Pac. REP. 385, the Supreme Court, in reversing a judgment obtained by the plaintiff against the defendant hospital, hands down an interesting and instructive opinion. The plaintiff was burned by a hot-water bottle placed in position by a nurse. The court says that "two questions are presented for determination: first, was the hospital a

charitable institution; second, if so, was it liable for an injury to a patient caused by the negligence of one of its nurses in the absence of allegation and proof of negligence of its officers or managers in the selection of such nurse?" The court answers the first question in the affirmative, and the second in the negative, saying, "the fact that the hospital charged for the accommodation and care bestowed on patients who were able to pay did not change its character, and that the rule is well established by legal precedents."

CLAIM AND SUIT.

It must be distinctly understood that whether there is or is not fault or want of skill on the part of the physician, he can be sued by a person claiming there is injury and damages, and the physician will be obliged to defend the suit, otherwise there will be a judgment by default taken against him. Unless the matter is settled before trial he must go through a trial to submit his side of the case and depend on the court and jury to consider his contentions sufficiently made out.

Insurance.—On receipt of the first demand made verbally or in writing and whether the latter is a legal paper or not, the physician should at once consult his insurance company, if he is insured for the full amount demanded. If not so covered or if there is any doubt as to being covered over the entire period, personal legal counsel should be seen. In some states the county or state medical society will furnish an attorney, but it will not pay any damages.

Some of the important provisions of the "physician's liability policy" of a leading insurance company are, "The company does hereby agree to indemnify the person (herein called the assured) named in statement 1 of the schedule of warranties, or the estate of said person, against loss from the liability imposed by law upon the assured for damages on account of any malpractice, error, or mistake: (*a*) of the assured in the practice of his profession during the term of this policy; (*b*) of any assistant of the assured while assisting the assured in the administration of medical or surgical treatment during the said term;

"To defend in the name and on behalf of the assured any suit brought against the assured, or against his estate, to enforce a claim, whether groundless or not, for damages on account of any alleged malpractice, error, or mistake: (*a*) of the assured in the practice of his profession during the term of this policy; (*b*) of any assistant of the assured while assisting the assured in the administration of medical or surgical treatment during the said term, subject to the following conditions:

"The company's liability for loss resulting from one claim or suit is limited to five thousand dollars, and, subject to the same limit for each claim or suit, the company's total liability under this policy is limited to fifteen thousand dollars. The expenses incurred by the company in defending any suit, including the interest on any verdict

or judgment and any costs taxed against the assured, will be paid by the company in addition to the limits expressed above.

"No person shall be deemed to be assisting the assured unless:

"(*a*) Such person is named in the schedule of warranties, or is a successor to, or a substitute for, a person so named; or,

"(*b*) Such person is a physician, surgeon, or dentist and is temporarily acting as a substitute for the assured in an emergency when the assured cannot act, or during a period in which the assured is not actively engaged in his professional duties; or,

"(*c*) Such person is actually assisting the assured (but not necessarily in the assured's presence) under the assured's instructions in the administration, by the assured, of medical or surgical treatment.

"This policy does not cover loss from liability for, or any suit based on, any malpractice, error, or mistake—(1) of any partner of the assured unless such partner is named in the schedule of warranties; (2) of the assured while in any degree whatever under the influence of intoxicants, anesthetics, or narcotics; (3) of the assured or any assistant of the assured while committing any criminal act.

"In case the assured becomes aware of any malpractice, error, or mistake covered hereunder, or any alleged malpractice, error, or mistake, the assured shall give immediate written notice thereof, with the fullest information obtainable at the time, to the company at its home office or to the agent who has countersigned this policy. If any claim is made against the assured on account of any malpractice, error, or mistake covered hereunder, or on account of any alleged malpractice, error, or mistake, the assured shall give like notice thereof with full particulars.

"If thereafter any suit is brought against the assured to enforce such a claim, the assured shall immediately forward to the company at its home office, or to the agent who has countersigned this policy, every summons or other process as soon as the same shall have been served on him. The assured shall at all times render to the company all coöperation and assistance within his power.

"The company shall not compromise any claim or settle any suit against the assured without the written consent of the assured.

"The defense of any suit under this policy by the company will be continued until a final decision is rendered in the assured's favor, or until the case has been appealed to the highest court to which an appeal can be taken or until the suit has been settled with the written consent of the assured.

"The assured shall not voluntarily assume any liability; nor incur any expense without the written consent of the company previously given; nor, except at his own cost, settle any claim; nor, excepting as provided in condition 6, interfere in any negotiations or legal proceedings conducted by the company on account of any claim."

An insurance company is only liable according to the terms of the policy. Actions are frequently brought for more than the amount limited in policies.

The insurance companies if liable to any extent will insist on conducting the defense, but they are not likely to object to personal counsel being associated, provided there is no difference of opinion as to the manner of conducting the defense. The company will usually make no charge for the services of its lawyers or the expenses of trial. These expenses of a trial are often heavy, especially if there is an appeal.

Compromise.—Compromise and settlement before trial is frequently possible and often advantageous in view of newspaper notoriety, loss of time, waiting for trial or final decision because of appeal, and effect of possible adverse verdict and judgment. Many have the mistaken notion that settlement concedes liability. If a settlement is sufficiently advantageous it is merely a business proposition. Offers of settlement are not usually permissible in evidence at a trial.

A contract of settlement is legal, and releases the physician from all further liability. In the cases of infants and incompetent persons the approval of the court will usually be necessary.

PREPARATION FOR TRIAL.

Assuming a settlement out of court to be impossible or disadvantageous, preparation for defense and trial should be made. In fact steps should be taken to those ends as soon as notice of claim is received regardless of chances or overtures for settlement; and to delay is hazardous. Courts and juries must be furnished proof of facts and circumstances; no diligence in locating favorable witnesses and evidence is too great. Here is where the great advantage of the physician having definite, accurate data, and photographic records of the prior condition, of his diagnosis, treatment and results will appear. He will be at a serious disadvantage without such to assist his lawyer in preparing his case and at the trial in his testimony.

The patient is apt to have a good memory for most of the circumstances which he thinks favorable to himself as it will be probably his only case of the kind, while the physician dealing with many patients may only with difficulty without data, recall events any one of which may be the winning point.

A complete definite bill of particulars of plaintiff's claims of injuries and damages should be obtained by agreement or order of the court as soon as possible.

It is usually advantageous to get by consent or order of the court a physical examination of the plaintiff at which examination expert witnesses can obtain at first hand data of the existing condition. Sometimes it is well to get an examination at the start of the action and another just before trial.

It is important to have the written medical authorities on the questions involved, and to keep in mind any letters, writings or lectures bearing on the disputed points the defendant physician may have made in the past.

Expert Witnesses.—There is a saying to the effect that a lawyer is a poor lawyer for himself and for the same reason it is desirable to have one or more physicians recognized in the profession as best qualified to speak on the issues, to advise and assist in the preparation for trial and to testify.

The necessity of competent expert witnesses is shown by the following cases: 123 Va. 113; 96 S.E.Rep. 360; Jour. Am. Med. Assn., LXXII, No. 15, p. 1100, quotes and approves, 78 Fed. Rep 442, "When a case concerns a highly specialized art . . . with respect to which a layman can have no knowledge at all, the court and jury must be dependent on expert evidence. There can be no other guide, and, where want of skill or attention is not shown by expert evidence applied to the facts, there is no evidence of it proper to be submitted to the jury. If no standard was established by the testimony of physicians, then the jury had no standard," and further quotes and approves, 23 Colo. App., 171, "This does not militate against the right of the jury to decide between conflicting testimony of different physicians or experts on the question of a standard; it only goes to the extent that, if in doubt upon any matter necessary to enable the jury to say that a standard has been fixed for its guidance by the testimony of such qualified witnesses, then it cannot from other incompetent evidence . . . raise a standard." 91 Minn. 219, 97 N.W.Rep. 882, was an action for damages for injuries alleged to have been caused by a physician's negligence and unskilfulness in the use of the roentgen rays. After trial in the lower court the action was dismissed. Plaintiff appealed to the Supreme Court where the ruling of the lower court was reversed. The defendant had made several roentgenograms of the plaintiff's chest in an attempt to locate a foreign body. A radiodermatitis resulted which required many months to heal, but it was healed at time of trial. The alleged negligence referred to improper technic. The plaintiff had an expert witness who was well acquainted with the *x*-rays and its properties because of his position as professor of physics in a college. This witness testified that the defendant's technic was faulty. The defendant objected to this testimony on the ground that the expert witness was not a physician and was therefore incompetent to testify as to the defendant's negligence in the use of the *x*-rays. The defendant contended that in an action for malpractice no expert witness was competent to testify who was not a physician of the same school as the defendant, *i. e.*, the same kind of a physician. The lower court rejected the evidence given by the plaintiff's expert witness, and the case was dismissed. The plaintiff appealed from this order assigning as error the dismissal and rejection of the testimony of the plaintiff's expert witness. The Supreme Court on appeal held: "The application of the *x*-rays to the plaintiff was not for purpose of treating a disease or ailment but for the purpose of locating, if possible, a foreign substance in the plaintiff's lung, therefore the *x*-rays were not in this case used as

a remedial agent. The *x*-rays may be applied by any person who has the requisite scientific knowledge of its properties and the court sees no reason why its application to the human body may not be explained by any person who understands it. If the application of the *x*-rays had been for medical purposes and not for the scientific purpose of discovering the presence of a foreign substance in his lungs it might be different. Order of the lower court reversed because of error in excluding the evidence of the plaintiff's expert witness and for dismissing the action." The ruling of the Supreme Court in this case would make it legal in that jurisdiction for persons other than physicians, provided they possess requisite knowledge of the *x*-rays, to employ the *x*-rays for diagnostic purposes such as the location of foreign bodies in human beings. It also permits a lay person who possesses proper knowledge of the *x*-rays to qualify as an expert witness in such actions for malpractice where the injury is alleged to have been caused by the *x*-rays.

In 127 Iowa, 456, 103 N.W.Rep. 360, the action was for damages for injury suffered by a patient through the alleged negligent use of the roentgen rays by the defendant physician in treating appendicitis. The plaintiff's expert witnesses testified that the *x*-ray treatment of appendicitis was not a proper one. It was also shown to the jury that the plaintiff was severely injured on the abdomen by the *x*-rays and suffered great pain and extended if not permanent disability thereby. The defendant objected to this evidence on the ground that the plaintiff's expert witnesses were not physicians of the same school as the defendant. The court overruled the objection. One of the plaintiff's expert witnesses was asked if he had not done several skin grafting operations on patients who had been injured as a result of the application of the *x*-rays by the defendant. The answer was in the affirmative. The defendant objected to this testimony on the ground that the plaintiff could not introduce evidence of other cases wherein the defendant had injured his patients by the *x*-rays, for the purpose of proving that he had been negligent in the case upon trial. The court also overruled this objection. The jury found a verdict for the plaintiff; the defendant appealed. The Supreme Court held: "The fact that the plaintiff was severely injured by exposure to the *x*-rays is clearly shown. We think this was a question of science and skill wholly independent of the methods of treatment of any particular school. It would hardly be contended by any school of healing that such 'burning' was proper treatment for any disease or in accordance with the theories of any school. Whatever error it may have been to allow competent expert witnesses from another school than that to which the defendant belonged to testify as to whether *x*-ray treatment was proper for appendicitis, the admission of the evidence did not prejudice the defendant. It was not proper for the plaintiff to introduce evidence showing that the defendant had injured patients at other times with the *x*-rays for the purpose of proving incompetence or negligence in this case. The

fact that the defendant had injured other persons is no proof that the defendant was incompetent or negligent in treating the plaintiff. The fact that the plaintiff was severely 'burned' is some evidence in itself that the treatment was improper. Judgment reversed for error in admission of the evidence as to injuries to other patients."

DEFENSES.

The defense or defenses should be outlined and prepared with all possible data in hand.

Statute of Limitations.—The defense first in importance is the technical one of the "statute of limitations" otherwise known as "limitation of actions" or "expiration of time for suit." Such limit is usually at least one year but this varies. It also depends, generally speaking, on whether the action is on contract or tort. In some jurisdictions the limitation is fixed by statute. In any case the choice or necessity of time and form of action must be ascertained from the law of the jurisdiction, but it is of extreme importance not only as to whether the circumstances warrant such a defense but also as to the insurance company's liability if insured. For instance, the insurance company may not cover the whole period of treatment.

The following are examples of how the courts have held with respect to this defense. In Ohio, 124 N.E.REP. 238; Jour. Am. Med. Assn., April 3, 1920, p. 972, the Supreme Court of Ohio, reversing a judgment affirmed by the Court of Appeals says "the plaintiff's petition stated that, December 29, 1913, the plaintiff sustained a fracture of both bones of her left leg above the ankle-joint and on that date employed the defendant to treat the case; that he was unsuccessful in his first attempt to reduce the fracture, and in about a week attempted again to set or reset the fractured limb, and again negligently failed to place the fractured ends of the bone together . . . and treated plaintiff until May, 1914. This action for damages was begun in April, 1915. The defendant's demurrer was on the ground that the plaintiff's right of action was barred by the 'statute of limitations,' and the question was, when did the statute begin to run as against the plaintiff; did more than one year intervene between the date on which her cause of action 'accrued' and the date on which such action was commenced?" The Supreme Court holds "this action was begun more than a year from the date of the fracture but less than a year from the date the patient was discharged. In an action for a breach of contract in such a case, the statute of limitations does not begin to run until the contract relation is terminated, and as under the allegations of the plaintiff's petition the contract of employment between the surgeon and his patient continued from December 29, 1913, to May, 1914, the plaintiff's right of action did not accrue until May, 1914, and was not barred by the statute of limitations when the action was brought."

In Ia. 162 N.W.REP. 217, where action was started in 1915, fourteen

years after treatment by *x*-rays and three years after development of a cancerous growth at the locality of *x*-ray "burn" the Supreme Court affirms a judgment in favor of the defendant in that the plaintiff's alleged cause of action was barred by the statute of limitations of time to sue which for negligence was much less than that for fraud, which was five years. The court says that it was alleged that in 1901 the plaintiff, then under seventeen years of age, broke his right wrist. It was set by other physicians. In June of that year the defendant made several *x*-ray exposures over a period of ten days for the purpose of making radiographs. That it was alleged as a result, the skin on the hand and wrist was "discolored;" that the defendant admitted that the *x*-rays had caused the "discoloration" and fraudulently informed the plaintiff that the injury was of no particular consequence and would be temporary in its effects, fraudulently concealing from the plaintiff the true nature of the injury; that the defendant then treated the "discoloration" for a time and it apparently disappeared, leaving a scar, but with the usual use of the hand; that the plaintiff and his parents fully relied on the statement and advice of the defendant as to the temporary effect of the *x*-rays and nothing further was done in regard thereto until 1912; that the use of the *x*-ray machine by the defendant produced a cancerous condition which was latent and dormant until 1912 and the plaintiff had no knowledge of said condition until then; that then the tissue of the right hand where the *x*-rays had been applied, broke down and became an epithelioma or cancerous growth, which caused great pain and necessitated amputation of the right forearm. The court says; "Was the plaintiff's cause of action concealed by the statement of the defendant that the original 'burning' was but temporary and was of no particular consequence and did the defendant fraudulently conceal the true effect produced by the use of the *x*-ray machine? The plaintiff alleged that he was 'burned' in 1901 and, as he alleged, by the negligence of the defendant. The fact was known by the plaintiff and his parents. All damages which subsequently developed were traceable to and based on that act. By the original act the plaintiff was injured and, as the petition alleged, by the negligence of the defendant. He would have been entitled to some damages at that time; and if it be true that cancer necessarily and in all cases is the result of such 'burning', or if cancer is the probable result, such fact could be shown as bearing on the question of damages in an action for the original injury. If cancer is not the necessary or probable result of such 'burning,' then the defendant's statement would be more or less of an opinion and, in that case, the fact that later, and in 1912, a cancerous condition did develop and the plaintiff's damages might therefore be increased, would not constitute a new cause of action. It would seem then that the plaintiff's cause of action accrued at the time of the original injury."

This last opinion is an important legal precedent. In some cases it would seem advisable to bring out at the trial the fact that sequelæ

are possible but improbable late results of radiodermatitis. It appears that if sequelæ develop as a result of an x-ray injury and said sequelæ develop subsequent to the expiration of the statute of limitations, such development does not constitute a new cause of action.

No Cause of Action.—The next defense will naturally be that there is no cause of action as the physician exercised a proper degree of skill and diligence. No presumption of negligence or want of skill can arise from the fact that a physician failed to effect a cure and in the absence of an agreement for specific results there can be no recovery. Previous cases cited support this. Ordinarily the burden of proof is on the plaintiff to establish the negligence or want of skill of the physician and the burden is on the defendant physician to prove his defenses. The weight of legal opinion appears to be that the existence or development of an injury or condition, after accepting a case, does not of itself establish *prima facie* negligence or want of skill. This theory has often been discussed as "*res ipsa loquitur*," or "the thing speaks for itself." In other words if the doctrine of *res ipsa loquitur* were to be generally applied in deciding an action for malpractice as it is in a few jurisdictions, the fact that the plaintiff patient was injured would of itself be *prima facie* proof or warrant an inference of negligence and lack of skill on the part of the defendant physician and it would not be necessary for the plaintiff to prove in the first instance the physician's negligence and lack of skill by testimony of witnesses. Such a doctrine would transfer directly or indirectly the burden of proof from the plaintiff to the defendant. The weight of opinion is against it.

The great advantage and importance of this defense is shown by the following examples in practice: "If the maxim '*res ipsa loquitur*' were applicable to a case like this, and a failure to cure were held to be evidence, however slight, of negligence on the part of the physician or surgeon causing the bad result, few would be courageous enough to practice the healing art, for they would have to assume financial liability for nearly all the ills that flesh is heir to," 78 Fed. Rep., 442. The latter case is cited and approved in 35 App. Case 57, Dist. Col.; the case was tried in the Supreme Court of the District of Columbia. It was an action against a physician for negligence in applying the x-rays for the purpose of diagnosing a fractured rib. The defendant was a specialist in the use of x-rays for diagnostic purposes to whom the plaintiff had been sent by her own physician. The plaintiff testified that she said to the defendant that she had been told the x-rays were dangerous and that the defendant told her that there was no more danger to her than there was to him, and that she was told by the defendant's wife who was his assistant that in a wide experience with the x-rays, they had not had an accident. The defendant had several expert witnesses who testified that his apparatus and technic of application had been in accordance with good practice; and that according to their experience and reading

it was impossible to guard absolutely against a "burn." The plaintiff asked the court to instruct the jury that if they decided that the plaintiff was "burned" in the course of the operation, that of itself would be evidence of negligence on the part of the defendant and cast on him the burden to prove that he was not negligent. The court refused to so instruct. The plaintiff appealed for that, for failure of defendant to warn her and for other reasons and the court says: "Generally speaking no inference of negligence can be drawn from the result of the treatment of a physician or surgeon. . . The result of the general rule is that, in an action for malpractice, the burden is always on the one alleging it, and even in exceptional cases, where a *prima facie* case is made out by proof of the operation and resultant injury, the doctrine of *res ipsa loquitur* does not relieve plaintiff of the burden imposed upon him of establishing his case by a preponderance of the evidence. . . The same rule should apply to practitioners using the *x*-rays as is applied to other practitioners." Affirmed on substantially the same reasons in Supreme Court 228 U. S. 233. It is said by the Appellate Court in Virginia, "The result, however bad, is of itself alone insufficient evidence to establish the unskilfulness or the negligence of a physician in such a case," 123 Va. 113—96 S.E.Rep. 360, Jour. Am. Med. Assn., LXXII, No. 15, p. 1100, in affirming a judgment for plaintiff where *x*-rays had been used in treatment of eczema.

A ruling on the question of *res ipsa loquitur*, in effect contrary to the weight of opinion, is given by the Supreme Court of Minnesota in the case of Minn. 159 N.W.Rep.1073, Jour. Am. Med. Assn., June 23, 1917, p. 1938. This is a jurisdiction that permits the jury to draw an "inference of negligence" in such cases. The Supreme Court affirmed a judgment for $2500 damages in favor of the plaintiff for injuries alleged to have been caused by the negligence of the defendant, a regularly licensed physician, in taking a roentgenogram. The court said "the evidence sustained a finding that the injury was due to the *x*-rays. To recover damages it was necessary to prove negligence on the part of the defendant. There was little direct evidence of negligence. The plaintiff claims that during the exposure the defendant made some exclamation to the effect that the machine was not working right. The plaintiff claims that the exposure was unduly long but the testimony does not strongly support such claim. The plaintiff's expert witness stated that a proper application of the rays would not have produced the result he found. The evidence is that with a proper machine and with a proper use of it a 'burn' is unusual. There is evidence that the machine was a proper one. The machine and its operation were wholly under the control of the defendant. Under such circumstances the rule of *res ipsa loquitur* applies. It does not follow from this, as the plaintiff's counsel argues, that the burden shifted to the defendant of proving freedom from negligence. *Res ipsa loquitur*, where it applies, does not convert the defendant's general issue into an affirmative defense. The *res ipsa loquitur* rule merely permits the jury

to draw an inference of negligence and the jury is to consider and weigh the inference in the light of all the facts and circumstances and give it such weight as tending to prove negligence as they deem is entitled to. It does not follow from what is here said that the *res ipsa loquitur* doctrine applies to a bad result or mishap coming from a physician's treatment. The rule does not apply in such cases." But so instructing a jury cannot but be very advantageous to a plaintiff.

A proper degree of skill and diligence is conclusively presumed by some courts where a physician has sued and recovered for his services. As is said in a New York case, "It must be considered as settled in this State, that a judgment in favor of a physician and surgeon for his professional services, rendered by a court of competent jurisdiction, in an action in which the defendant appeared and answered, setting up a defense which he maintained at the trial, or in an action in which he appeared and signed and filed a written confession of judgment for the amount of the services, is a bar to an action for malpractice by that defendant against that physician and surgeon for malpractice in rendering those services," 75 N. Y. 150. This case is cited in 175 N. Y. 229, 237, "it thus became a case in which two claims could not coexist; where if the plaintiff was entitled to have his claim allowed, the defendant would be precluded from recovery." Also cited in 151 N. Y. 122, 127, "the estoppel of the judgment extends to every question relating to the parties even though they were not litigated or considered in that proceeding." But it is said in 21 R. C. L. 403, "that the weight of authority is contra except when the malpractice is actually set up and litigated in the action for services."

Estoppel.—A defense in the nature of an estoppel may be used where a person consults a physician as to treatment that the physician believes will be unsuccessful or will leave a deformity or disfigurement or other serious results, and he so informs the prospective patient and is nevertheless urged to give the treatment and there is no lack of skill or care on his part; he should not then be held liable for the results. Of course this would not excuse an operation he believes would kill the patient, nor always where it would endanger life. An authority so holding as to the main proposition is 21 R. C. L. 403, which states "If a patient is fully cognizant of the nature of the specific treatment which he is about to get, or if he actually directs a specific act, such as an operation which should not be performed, it would seem that he could not properly complain later that such treatment or act constituted malpractice for which he should recover. Here it would seem that he has sought to rely upon his own judgment rather than on that of the physician and can complain only if the physician negligently performed the act or treatment that the patient ordered," citing 68 L. R. A. 432, a New Hampshire case.

Waiver.—"Consent of the patient to the abandonment of the case by a physician may be a defense to a subsequent action for malpractice," 30 Cyc. 1582.

Contributory Negligence.—Contributory negligence on the part of the injured patient is one of the very important defenses. When the relationship of physician and patient is once created the patient owes a duty of care not only to the physician but to himself. As a general rule the patient will not be allowed to recover from the physician if the latter can show that the patient's negligence contributed to the injury simultaneously with the physician's negligence. "It is the duty of a patient to coöperate with his physician and conform to the necessary prescriptions and treatment, and follow all reasonable instructions given. Therefore it is a good defense to an action for malpractice, where the physician or surgeon is charged with negligence or the non-observance of proper care or the want of skill in performing the services undertaken, that the patient was guilty of negligence at the time which conduced or contributed to produce the injury complained of," 30 Cyc. 1580.

Instances of contributory negligence would be where the patient fails to follow instructions, acts in a manner to prevent a recovery, adopts some different simultaneous course of treatment, fails to return for treatment, and refuses to permit proper treatment or completion of treatment. In 92 Kan. 801, an action against a physician for malpractice in the use of *x*-rays for diagnostic purposes, the defendant claimed that the damage resulted because the plaintiff failed to return for treatment of the alleged injury. The verdict was against the defendant in the lower court. The appellate court decided that "the fact that a patient discharges a physician or quits his care and employs another physician is not in itself evidence of contributory negligence. There was evidence that the patient had continued under the professional care of the defendant for a long time after the 'burn' was inflicted and that it grew no better but became continually worse."

Antecedent Condition.—Another defense would be that of the antecedent condition of the patient including the consideration of natural and artificial idiosyncrasies. This would not be in all cases a complete defense but while it might not avoid the assessment of damages it would be important in reducing them if an unfavorable prior condition can be shown. Usually it cannot be employed to prove lack of negligence.

Idiosyncrasy or hypersensitiveness to *x*-rays is a defense frequently employed in malpractice suits and precedents have been established. In the action 204 S.W.Rep. 450 Tex., the plaintiff patient in the district court alleged negligence on the part of the defendant physician in the application of the *x*-rays in the treatment of eczema, said alleged negligence resulting in "burning" the plaintiff. The plaintiff alleged among other reasons that the *x*-rays were a dangerous agent; that they had been improperly applied by the defendant; that the defendant left the room during the treatments whereas he should have remained. The defendant set up as a defense that the injury of which the patient complained was caused by hypersensitiveness of the plaintiff's skin to

the effect of the x-rays, and that he could not have discovered this idiosyncrasy prior to the treatment. Although expert witnesses had testified that the plaintiff's skin was hypersensitive, yet the judge did not instruct the jury to take this into consideration. The verdict was for the plaintiff in the sum of $2500. The defendant appealed, his main ground of appeal being the fact that the judge in the lower court refused to instruct the jury that idiosyncrasy was a defense. The appellate court ruled; "the defense of the defendant, *i. e.*, that hypersensitiveness of the skin of the plaintiff to the x-rays was the proximate cause of the injury, was both pleaded and supported by evidence. A physician is not required to take precaution against a peculiar temperament or abnormal idiosyncrasy of which he has no knowledge and for detecting which there is no means. The evidence shows that the defendant did not know of the plaintiff's hypersensitiveness and that there is no way to ascertain such a peculiarity prior to treatment. The testimony of the defendant's expert witnesses as well as the testimony of the plaintiff's own expert witness, is sufficient to authorize a finding by the jury that the plaintiff did have a hypersensitive skin and that this peculiarity was the proximate cause of the injury. We think that the jury should have been instructed, that if they believed that the proximate cause of the plaintiff's injury was his abnormal hypersensitiveness but for which the injury would not have occurred, then the verdict should be for the defendant. Judgment of the lower court reversed and case remanded."

It would appear as though the question of idiosyncrasy might enter a case on both sides . . . that it might be used both by the plaintiff and by the defendant. It would be of advantage to the plaintiff if and when such a peculiarity could be detected by due care and skill. There is likely to be a dispute between the expert witnesses for the defendant and those of the plaintiff relative to the possibility of idiosyncrasy and its discovery before or during treatment. It rests with the jury to decide whether or not the defendant possessed knowledge relative to the possibility of idiosyncrasy and whether or not he used due care and skill in the light of such knowledge. In the case of 91 Minn. 219, 97 N.W.Rep. 882, the defendant conceded that the x-rays frequently "burned" the body of a patient, but that some persons are not susceptible to its influence while others are and that it is impossible to determine in advance who are and who are not susceptible to injurious effects. On appeal the Supreme Court ruled: "that such were questions of fact for the jury to determine."

Mitigation Defenses.—It is always important and proper to bring to the attention of the court and jury relevant evidence bearing on matters not in themselves complete defenses because of difficulty of proof of proper skill and care or for other reasons, but tending to mitigate the damages. The agreement of a patient not to hold the physician liable, the consent to dangerous or uncertain treatment, or inducing treatment by persistent coaxing, would be examples that

often could be advantageously presented. Also the negligence of the patient after negligence or want of skill by the physician, aggravation by the patient of the injury or condition, no attempt to cure or improve the same, or negligence or want of skill of another doctor, improvement or entire recovery at time of the trial, and no permanent injury, are important points to be made use of in proper cases. "If any act of the patient had been shown by the evidence to have caused an aggravation of the injury, such evidence would probably have been pertinent in mitigation of damages, but the mere fact of the change of physicians does not raise the presumption that damages were increased thereby," 92 Kan. 801. "If a patient should disobey the instructions of a physician and such disobedience should serve merely to enhance or aggravate the injury caused by the physician originally, then the amount of damages recoverable would be reduced," 21 R.C.L. 402. In the action 49 Wash. 557, the plaintiff, suffering from an "ailment of the foot," consulted the defendant who prescribed and administered *x*-ray treatment for the same. After daily treatment for about two weeks the foot began to swell, itch and burn. Further treatment resulted in a "burn." The plaintiff alleged that the foot was permanently injured, that she would be a cripple for life and that amputation might be necessary. The negligence charged was that the defendant failed to properly protect the foot from the *x*-rays, that he failed to discontinue the treatment when he should have done so, and improper position of the apparatus. There was testimony to the effect that there was an *x*-ray "burn" of the "fourth" degree and that such an injury is generally incurable. There was a dispute as to whether or not the treatment and technic were correct. The defendant set up as defenses, that the injury was due largely if not entirely to an ointment which spread from the affected part to other parts of the foot, because the plaintiff had used her foot contrary to instructions, that there was no *x*-ray "burn," that the treatment was proper, and that the foot was cured at the time of trial; furthermore, that the *x*-rays were a comparatively new discovery and were not well understood by physicians and surgeons in such communities as where applied. The lower court instructed the jury that "if the plaintiff quit treatment before the defendant was willing that she should do so and that if any evil result came from such action on the plaintiff's part, then the plaintiff should not recover." Also, "that if the plaintiff did not follow with proper care and diligence, the defendant's instructions as to how she should act and as to how she should treat and care for her foot and any injury to her foot resulted therefrom, the plaintiff should not recover." The verdict in the lower court was for the defendant. The plaintiff appealed. The Supreme Court held on appeal; "the instruction to the jury was erroneous. It would be a harsh doctrine to say that if a patient by a subsequent or independent negligent act increases or augments the injury caused by a negligent or incompetent physician, that then she cannot recover. Such is not the law. It

is proper that such aggravation on the part of a patient may be shown in mitigation of damages but it does not relieve against the primary liability. The court cited as supporting this opinion 86 Pa. St. 297; 46 Ore. 424; 75 N.Y. 12; 130 N.Y. 325; 39 Vt. 447. The court further held that if it should appear that a physician was ignorant of the effect of *x*-ray exposures the jury might well conclude that the use of such a dangerous agency by one having little or no knowledge as to the probable consequences was negligence *per se;* it reversed the judgment and sent the case back for a new trial. In an action for damages alleged to have resulted from *x*-rays used to remove hair from the face, a judge of the New York Supreme Court instructed the jury that it might, in considering damages if any, take into consideration the appearance of the plaintiff's face before treatment (cosmetic disfigurement of hypertrichosis) and her desire to have it removed.

TRIAL.

The suit will ordinarily be tried by judge and jury.

The judge generally speaking rules on the law and on the admission or rejection of evidence; he charges and instructs the jury on the law and may give a synopsis of the case made out by each side.

If there is any doubt or dispute as to the facts, in issue, the case goes to the jury to decide the facts.

The judge can sometimes order a new trial, set aside the verdict or reduce a verdict.

Either side can appeal.

The appellate court may affirm or reverse the lower court; it may send the case back for a new trial; only the lawyers appear in this court.

In the large cities such cases often take one or more years to be reached after listing.

CONCLUSION.

Need more be said as to thorough preparation for trial? With so many points to be considered all available time should be devoted to getting them in shape to present once and for all everything favorable.

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